ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

НАУКОВО-МЕТОДИЧНИЙ ЖУРНАЛ

ТЕОРІЯ ТА МЕТОДИКА ФІЗИЧНОГО ВИХОВАННЯ

[Physical Education Theory and Methodology]
[Teorìâ ta Metodika Fìzičnogo Vihovannâ]

№ 5 · Том 24 · жовтень 2024

Адреса журналу в Інтернет:
https://tmfv.com.ua
https://doi.org/10.17309/tmfv.2024.5

/ ОВС ТОВ
Харків
Україна

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN 1993-7989-L

Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ
Abbreviated key-title: Teor. metod. fiz. vihov.

Науково-методичний журнал
Scientific-methodological journal

Шість випусків на рік. Заснований у 2000 році
Six issues per year. Established in 2000

https://www.tmfv.com.ua. E-mail: tmfv@tmfv.com.ua

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ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN 1993-7989-L

Теорія та методика фізичного виховання

Науково-методичний журнал

Жовтень 2024. Том 24, № 5
https://doi.org/10.17309/tmfv.2024.5

Зміст

ОРИГІНАЛЬНІ НАУКОВІ СТАТТІ

ОГЛЯДОВІ СТАТТІ

ISSN 1993-7989 (print)
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Physical Education Theory and Methodology

Scientific-methodological journal

October 2024. Vol. 24, Num. 5
https://doi.org/10.17309/tmfv.2024.5

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ORIGINAL SCIENTIFIC ARTICLES

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ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Considering the Validity and Reliability Testing of a Digital Punch Measuring Tool in Young Combat Athletes

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Accepted for Publication: August 27, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.01

Abstract

Objectives. The application of technology in sports, including combat sports, is increasing rapidly. This study aimed to determine the validity and reliability of digital punch-measuring tools in young combat athletes.

Materials and methods. A total of 28 participants, consisting of 9 males (age 15.88 ± 1.6 years, height 162.56 ± 6.8 cm, weight 55.2 ± 10.2 kg, BMI 20.7 ± 2.5, PBF 14.57 ± 4.5 %) and 19 females (age 14.5 ± 1.5 years, height 154.3 ± 5.4 cm, weight 48.6 ± 8.5 kg, BMI 20.4 ± 3.2, PBF 27.4 ± 6.5 %) from the martial arts branch involved in the study and were included in data collection. The method used in this study was the Pearson Product-Moment Correlation Coefficient, analyzed using Minitab version 21. All research subjects engaged in a warm-up routine before performing three punches with both their right and left arms.

Results. The findings of this study indicate positive validity (right 0.856, left 0.875) and reliability (right 0.8037, left 0.8209) in measuring both right and left punches.

Conclusions. Thus, digital punch measuring tools can be used for training to improve punches and as an initial test tool for implementing effective training programs and monitoring the development of combat athletes.

Keywords: digital punch measuring tools, martial arts sports, young athletes.

Introduction

Martial arts is a popular sport in various countries (Bishop et al., 2013; Rydzik et al., 2024; Vertonghen & Theeboom, 2010). This sport requires good aerobic and anaerobic abilities, especially for the explosive power and strength components (Chaabène et al., 2015). This is related to the athlete's explosive movement ability when kicking and punching an opponent (Walilko et al., 2005). For example, in the sport of boxing, where quality punching movements are the main movement that determines victory during a fight (Chaabène et al., 2015). According to (Lenetsky et al., 2013) the ability to produce high levels of muscle strength is the key to success in punching movements, especially in professional boxing. Apart from that, many previous studies also explain that the strength of the blow is a determining factor in the outcomes of the fight (Bianco et al., 2013).

Unfortunately, specific measurements of punch strength in youth martial arts sports are still limited. Young athletes themselves are still not at their peak in terms of ability, so their developmental characteristics are important to measure and monitor (Difiori et al., 2014). Monitoring the number of hours of exercise and the movement techniques used may play a role in reducing the risk of injury (Demorest et al., 2016). Meanwhile, due to limited costs and facilities, most punch strength is only measured conventionally using similar movement methods, such as push-ups and bench presses. However, it is felt that this is still unable to describe specific muscle groups and movements in martial arts, considering that the muscle involvement when hitting is more complex.

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It is proven from research findings (Lopez-Laval et al., 2020) that several variables are not related between bench press ability and rear arm punch speed. There needs to be a tool that can be measured digitally to optimize it.

For several decades there have been tools used to measure punch strength, including heavy bags, force plates, strain gauge-based measurement systems, and accelerometers (Falco et al., 2009; Pędzich et al., 2006). However, each of these tools still has several shortcomings to be implemented, ranging from cost, operation, and data collection to the methods used. For example, research conducted (Lopez-Laval et al., 2020) to measure punching performance only used punch speed as an indicator, while the force generated from the punch has not yet been assessed. In another study, force measurements were carried out using modified force plates that was attached to the wall with a body protector coated on the outside to minimize hard impacts that could cause injury to athletes (Loturco, 2016). However, this method is only limited to certain punching movements such as jab and straight, while the types of punches involved in combat sports vary greatly. Apart from that, the target designed for this tool is still limited to one point, while we know that in martial arts sports, the target of the blow is on the opponent's body in more than one place and requires precise and fast timing to deliver the blow based on the opportunities obtained during the fight.

To overcome some of these obstacles, we are developing a tool for measuring punch strength in martial arts athletes called Sansak Digital or Sandit (Surabaya State University, Surabaya, Indonesia). This tool uses the same measurement method as (Del Vecchio et al., 2022), where there are plates, foam, and pressure sensors using a load cell, which is integrated with software on a laptop via a USB cable connection. Even though the Sandit does not have an accelerometer, this tool has the advantage of having 4 hitting target points that depict the opponent's body segments and is equipped with reaction action indicator lights so that it can specifically train athletes' martial arts punching techniques and reaction speed simultaneously. Considering the importance of validity and reliability of a tool (Aragon-Vargas, 2000; Firmansyah et al., 2024). Currently, the weakness of Sandit is that there is no tool reliability testing that can strengthen the reasons for using this tool in the training process and testing.

Therefore, this study aims to test the validity and reliability of digital sansak on young athletes in martial arts sports. If this tool is proven to have a good level of reliability, it can be a solution to some of the problems experienced by previous test tools.

Material and Method

Participant

A total of 28 people with composition, 9 men (age 15.88 ± 1.6, height 162.56 ± 6.8, weight 55.2 ± 10.2, BMI 20.7 ± 2.5, PBF 14.57 ± 4.5) and 19 women (age 14.5 ± 1.5, height body 154.3 ± 5.4, weight 48.6 ± 8.5, BMI 20.4 ± 3.2, PBF 27.4 ± 6.5) from the martial arts branch participated in data collection. The method in this research uses the Pearson Product validity and reliability test with Minitab software version 21. The inclusion criteria for this research are the number of years of experience. Had no history of injury to either the upper or lower extremities during the study (Ambroży et al., 2022) tactics, and movement structure, and requires an adequate level of motor skills as a foundation for activities during competitions. General physical fitness, defined as the effect of the externalization of motor skills, is the basis for athletic training regardless of the sport. The aim of this study was to determine the effect of modified training based on the principles of CrossFit on the development of general physical fitness in a group of kickboxers compared to a control group. Methods: The study was experimental in nature and was conducted in a group of 60 kickboxers, divided into experimental and control groups. Participants were selected by purposive sampling, and the criteria were training experience, sports skill level (minimum class 1 athletes. This research has received ethical permission from Number: 795/KEP. 01/UNISA-BANDUNG/V/2024, referring to the Declaration of Helsinki.

Procedure

Before data collection, all athletes filled out informed consent, a sports injury screening using modified questions from (Fuller et al., 2006). Next, they tested height using Metrisis (Surakarta, Indonesia) and body composition using InBody 270 (Seoul, South Korea). After that, they were asked to warm up for 30 minutes and hit the digital punch three times each on the right and left arm in succession. Each person who makes a punch has their strength calculated on a tool with a load cell system installed behind the pad on the Sandit and recorded automatically in the internal software. The force applied to the plate or pad is then sent via a USB cable connected to a laptop into Newton's (N) data.

Statistical Analysis

This research uses the Pearson correlation validity and reliability test. After all the data has been collected, it goes to the analysis stage using Minitab version 21 (Pennsylvania, USA) with the Anderson-Darling normality test method to determine the overall data distribution. The Pearson Correlation Product was chosen because the data obtained was normally distributed and then entered the validity testing stage with a CI of 95 % and an r-table value = 0.37 from a total of 28 subjects. This validity testing method is the same as that used in previous studies (Deiss et al., 2024; Sahu et al., 2024) in clinics without an IKD, clinicians default to using handheld dynamometers (HHD). Referring to (Ferreira et al., 2021) which can provide valid information to implement effective treatment and exercise training. The purpose of the study was to examine the instrumental validity of the hanging scale (HS research, the reliability test in this study uses Cronbach's Alpha with a value of > 0.7, so the reliability test can be fulfilled). Testing of the validity and reliability of punch strength was carried out on each side, both the left and right arms. Data is presented in the form of means and standard deviation.

Results

Below is a table containing the characteristics of the subjects who participated in this research:

Table 1. Characteristic of Participant

	Age (years)	Weight (kg)	Height (cm)	BMI	PBF (%)
Male	15.88 ± 1.69	55.20 ± 10.11	162.56 ± 6.84	20.74 ± 2.50	14.57 ± 4.52
Female	14.57 ± 4.57	48.66 ± 8.53	154.37 ± 5.46	20.41 ± 3.28	27.40 ± 6.54

Notes: BMI = Body Mass Index, PBF = Percent Body Fats

Validity Results

The results of this study show that all r-values exceed the r-table value with a total of 28 subjects (0.37). It can be seen from table 1 where the right punch value after statistical testing uses Pearson's to test the level of validity of the digital sansak with r-values in sequence Trial 1 (0.83), Trial 2 (0.88), and Trial 3 (0.85). Meanwhile, the results of the left blow can also be seen from Trial 1 (0.82), Trial 2 (0.91), and Trial 3 (0.87).

Table 2. Validity Test Pearson's

Validity of	r-value Trial 1	r-value Trial 2	r-value Trial 3	r = table (n = 28)
Right Punch	0.83	0.88	0.85	0.37
Left Punch	0.82	0.91	0.87	0.37

Reliability Results

In the reliability test results, researchers used Cronbach's Alpha test to find out the level of consistency of the digital punch when used to measure the strength of the blow over three trials. As we can see in Table 4 the results of Cronbach's Alpha test show that the value for the right hit is 0.80, while for the left hit the value is 0.82.

Table 3. Punch Strength / Trial

	Trial 1	Trial 2	Trial 3
Right Punch (N)	66.49 ± 33.16	85.25 ± 41.12	84.43 ± 49.73
Left Punch (N)	61.74 ± 32.24	88.70 ± 48.33	78.64 ± 53.69

Notes: (N) = Newton

Table 4. Reliability Test Cronbach's Alpha

Reliability of	n	CA
Right Punch	28	0.80
Left Punch	28	0.82

Notes: n = all participants, CA = Cronbach's Alpha Value (> 0.7)

Discussion

This research aims to test the validity and reliability of digital sansak. Like most previous research (Mondin et al., 2018; Menzel & Potthast, 2021) tests how reliable a tool is before applying it to sports training. This technology is designed to help coaches monitor and measure how strong the blows produced by their athletes. Digital-based measurements minimize inaccurate decision-making processes because assessments are carried out objectively, not subjectively. In addition, accurate and variable measurement data is important for monitoring training progress and results (Lambert et al., 2018). In this test, the validity test results (Table 2) were obtained, both (left and right arms) were valid (r-value > r-table, n = 28), meaning that this tool could be trusted and used in the next trial with a larger number of subjects. In research conducted by (Soga et al., 2023), the small number of subjects could influence the results of the statistical analysis carried out.

The use of technology in the training process needs to be developed so that it can monitor the training process objectively to make the data collection process easier. For example, the use of the global positioning system (GPS) to monitor the physical demands during soccer training on the field (Santos et al., 2024), measuring hamstring muscle strength to determine appropriate and measurable training programs for handball athletes (Firmansyah et al., 2024) weight 62.6 ± 20.7 kg, height 173.6 ± 5.0 cm, BMI 22.1 ± 4.0 kg/m^2, Sprinters (Yeung et al., 2009), American Football (Feeley et al., 2008), and other competitive sports with a predominance of high-intensity sprint movements. It is also important to monitor heart rate periodically to determine the appropriate training zone (Sylta et al., 2014) 13 female; 25 ± 4 y; 70 ± 11 kg; 76 ± 7 mL · min^{-1} · kg^{-1} VO_2max.

Young martial arts athletes need to measure arm muscle strength as material for coach evaluation. Speed is not enough, increasing punching power is the goal of training in combat sports (Dunn et al., 2022). Because punching power is an important factor in combat sports (Lambert et al., 2018). The number of punching movements may influence the amount of force produced so that the force exerted will vary each time. The digital sansak was proven to have a high level of reliability, where after carrying out a reliability test for three attempts at hitting the results were very good (Cronbach's Alpha > 0.07) (Table 4). Therefore, digital punching can be recommended for repeated measurement of punch strength.

Limitations in this research include the relatively small number of subjects tested. Then the second limitation is that there is no other tool that can be categorized as the gold standard for measuring punch strength as a comparison to the results obtained from digital sansak. Future research is recommended to use a larger number of subjects with various ages, genders, and punch variations. Then using a tool that has a gold standard can show how big the margin is between Sandit and that tool.

Conclusions

This research concludes that the digital sansak is a valid and reliable tool for measuring punching strength. So, it can help in the martial arts training process to assess how strong a blow can be produced. This technology can also be used to assess blows repeatedly, even though the number of subjects used is still small.

Conflict of interest

The authors declare that there is no conflict of interest.

Acknowledgment

This study was funded by Universitas Negeri Surabaya.

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Перевірка валідності та надійності використання цифрового інструменту для вимірювання сили удару кулаком у юних спортсменів-єдиноборців

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Реферат. Стаття: 6 с., 4 табл., 30 джерел.

Мета дослідження. Застосування технологій у спорті, зокрема у спортивних єдиноборствах, стрімко зростає. Мета цього дослідження полягала у визначенні валідності та надійності використання цифрових інструментів для вимірювання сили удару кулаком у юних спортсменів-єдиноборців.

Матеріали та методи. У дослідженні взяли участь загалом 28 осіб: 9 – чоловічої статі (вік 15,88 ± 1,6 року, зріст 162,56 ± 6,8 см, вага 55,2 ± 10,2 кг, ІМТ 20,7 ± 2,5, відсоток жирової маси тіла 14,57 ± 4,5%) та 19 – жіночої статі (вік 14,5 ± 1,5 років, зріст 154,3 ± 5,4 см, вага 48,6 ± 8,5 кг, ІМТ 20,4 ± 3,2, відсоток жирової маси тіла 27,4 ± 6,5 %), які займаються бойовими мистецтвами та були включені до збору даних. Для аналізу результатів дослідження було застосовано коефіцієнт кореляції моменту добутку Пірсона ("Pearson Product-Moment Correlation") за допомогою програми Minitab версії 21. Усі досліджувані займалися розминкою перед виконанням трьох ударів кулаком правою та лівою рукою.

Результати. Результати цього дослідження свідчать про позитивні показники валідності (правий 0,856, лівий 0,875) і надійності (правий 0,8037, лівий 0,8209) у процесі вимірювання сили удару кулаком як правою, так і лівою рукою.

Висновки. Таким чином, цифрові інструменти для вимірювання сили удару кулаком можна використовувати для тренувань з метою вдосконалення таких ударів, а також як початковий інструмент тестування задля впровадження ефективних тренувальних програм та моніторингу розвитку спортсменів-єдиноборців.

Ключові слова: цифрові інструменти для вимірювання сили удару кулаком, бойові мистецтва, юні спортсмени.

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Cite this article as: Budijono, A. P., Puspitaningayu, P., Kurniawan, W. D., Firmansyah, A., Ayubi, N., Arsapakdee, K., & Putro, A. B. (2024). Considering the Validity and Reliability Testing of a Digital Punch Measuring Tool in Young Combat Athletes. *Physical Education Theory and Methodology, 24*(5), 683-688. https://doi.org/10.17309/tmfv.2024.5.01

Received: 08.06.2024. Accepted: 26.07.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fizičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Diagnosing the Level of Forming the Practical Component of Future Physical Education and Sports Specialists' Readiness for Educational Activities to achieve Sustainable Development

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Accepted for Publication: September 11, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.02

Abstract

Background. Ukraine's support for sustainable development strategies and European integration processes requires the training of specialists engaged in sustainable development educational activities.

Objectives. The study aimed to show the impact of the experimental methodological system on the forming the practical component of physical education for future physical education and sports specialists' readiness for educational activities contributing to sustainable development.

Materials and methods. The study involved 390 students from the faculties of physical education of the T. H. Shevchenko National University "Chernihiv Colehium", the National University of Life and Environmental Sciences of Ukraine, Sumy State University, and Sumy State Pedagogical University named after A. S. Makarenko, future specialists in physical culture and sports. The students were informed about the features of the study and voluntarily participated in the pedagogical experiment. The participants of the study are represented by both sexes of different courses, from which the control and experimental groups were formed. The research methods used include the study and analysis of scientific and scientific-methodical literature, pedagogical experiments, surveys, testing, analyses, synthesis and generalisation of information, as well as methods of mathematical statistics.

Results. At the beginning of the study, 93.33 % of students in the control group and 94.44 % of students in the experimental group had a low level of the practical component of readiness for educational activities contributing to sustainable development. The final stage of the study revealed a significant improvement in the studied indicator within the experimental group: 43.33 % of students demonstrated a low level of the practical component of the studied readiness, 16.67 % had a satisfactory level, 31.11 % showed an average level, and 8.89 % had a high level. The corresponding changes were observed in all defined indicators: activities for sustainable development in physical education classes or sectional sports lessons; activities for sustainable development during extracurricular work of a physical education teacher or outside the sectional work of a sports coach with a population of different age groups; and activities for sustainable development in managerial positions. In the control group, at the end of the experiment, no significant changes were found in the the practical component levels of future physical education and sports specialists' readiness to participate in educational activities for sustainable development.

Conclusions. The findings of the pedagogical experiment confirmed the positive impact of the developed methodological system on the forming the practical component of future physical culture and sports specialists' readiness to participate in educational activities for sustainable development.

Keywords: sustainable development, education, physical education, sports, teacher of physical education, sport coach.

Introduction

In the second half of the twentieth century, because of countries' rapid economic development, humanity inherited some global problems. The need to address these issues has led to the emergence of a global strategy for sustainable development (Shapar, 2006). Achieving social justice, economic development, restoration and preservation of nature requires cooperation among all countries in various fields, as well as appropriate reorientation of education to sustainable development (UNECE Strategy, 2005).

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ТМФВ
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Despite Ukraine's aspirations for European integration (Association, 2014) and ongoing reforms in Ukrainian education, the transition to sustainable education in Ukraine is not systematically implemented and is not widely studied (Koreneva, 2018). However, in developed countries such as Canada, Australia, the United States of America, the United Kingdom, Germany, Sweden, and other developed countries of the European Union, the issue of education for sustainable development is being studied very intensively (Gorski et al., 2023; Grosseck et al., 2019), and in a number of countries is being implemented at the state level (UNESCO Shaping, 2014). After all, education is recognised as a factor that can contribute to sustainable development goals (United Nations, 1992).

Education for sustainable development is not just about transferring specific knowledge or changing behaviour, but about changing values, about the ability to acquire and apply knowledge in a holistic way, to be able to find cause and effect relationships and to predict the consequences of activities, about acquiring relevant competencies, critical and systemic thinking and lifelong learning that affect all segments of the population (Leal Filho, 2021).

Sport is also an important factor in sustainable development (Sport as an enabler, 2018) and is actively involved in addressing various sustainability issues abroad (IOC Sustainability, 2024; The Sustainability Report, 2024). Scientists consider the commonality of the goals of sustainable development, sport and physical culture (Chernushenko, 2003; Chen et al., 2018), analyse the legacy of the Olympic Games for sustainability (Chappelet, 2008; Cashman, 2006), explore the possibility of educational activities for the sustainable development of sports coaches (Perez-Ordas et al, 2018) and educational aspects of sustainable development in the field of physical education and sport because 'healthy sport requires a healthy environment', on the other hand, 'unhealthy environments hinder people's motivation to participate in sport and can negatively affect athletes' performance' (Oben, 2009; Lundvall & Fröberg, 2022).

To implement education for sustainable development in the practice of physical education teachers, scientists propose the following steps:

- critical analysis and revision of curricula and guidelines for physical education and sport programmes in each country to determine which parts of Agenda 2030 and which sustainable development goals are relevant to education for sustainable development in physical education and sport;
- rethinking the prospects of physical education in the field of physical education in the direction of transformational learning, when there is a shift in focus "from self to others" and "perception of oneself as part of the whole" – society and the environment;
- reorientation of views on health and well-being from a holistic perspective to increase teachers' and students' skills and knowledge about the interaction and interconnection between health, well-being and the environment, which can be achieved by incorporating cross-curricular topics and competences into key physical education concepts (Lundvall & Fröberg, 2022).

Research suggests that physical education students and physical education teachers: have too general an understanding of sustainability and link it to either an environmental perspective or social skills; do not have a clear understanding of the strategies that are appropriate for implementing sustainable development goals in physical education classes. Among the reasons that prevent them from implementing sustainable development education in the classroom are a lack of knowledge and appropriate guidance on how to implement SDGs, as well as a lack of time and resources for physical education. Physical education itself is positively assessed for fostering the values necessary for sustainable development (Baena-Morales et al., 2022; Merma-Molina et al., 2023). The involvement of physical education in addressing practical sustainability issues in local schools and communities has received positive feedback and a desire to continue to work in this area (Lynch & Boylan, 2016).

In Ukraine, the activities of the physical education and sports sector from the perspective of "for sustainable development" is hardly covered by the public. There are a small number of theoretical works that deal with individual components of sustainable development (Imas et al., 2017; Kachan & Prystynskyi, 2022) and practical activities of environmental or social nature without any focus on sustainable development (Imas et al., 2020; Bubka & Bulatova, 2017).

In 2011, the United Nations Economic and Social Council defined teacher competencies in sustainable education. According to this document, each competence for sustainable development has the following four components: "learning to know (the teacher understands...), learning to do (the teacher is able to...), learning to live together (the teacher works with others...), learning to be (the teacher is a person who...)" (UNECE Learning, 2011). In Ukraine, the content of these competencies has been proposed for future specialists in physical culture and sports (Tsyhura, 2020), but currently, education for sustainable development in higher education institutions is not systematic. Therefore, we focused on the development and implementation of a methodological system to train future physical education and sports professionals for sustainable educational activities. We previously found that specialists in this field are not sufficiently aware of the issues of sustainable development, do not understand the essence and depth of sustainable development goals, are able to establish the connection of physical culture and sports only with the sustainable development goals of the social direction (Tsyhura & Harkusha, 2023), and need to acquire knowledge on this issue for their professional activities (Tsyhura, 2021). One component of the readiness of future physical education and sport specialists for sustainable development educational activities is active practical work.

The aim of this study is to show the impact of the experimental methodological system on the formation of the practical component of future physical education and sports specialists' readiness for educational activities that promote sustainable development.

Materials and Methods

Participants

The study involved 390 future specialists in physical culture and sports who were students of the faculties of physical education of T. H. Shevchenko National University

"Chernihiv Colehium", the National University of Life and Environmental Sciences of Ukraine, Sumy State University, and Sumy State Pedagogical University named after A.S. Makarenko. Students were informed about the features of the study and voluntarily participated in the pedagogical experiment. To conduct the pedagogical experiment, control and experimental groups were formed. The participants of the study are represented by both sexes in different courses. At the ascertaining stage of the experiment, both groups (control and experimental) had 90 students each: the control group consisted of 52 boys (57.8 %) and 38 girls (42.2 %); the experimental group consisted of 55 boys (61.1 %) and 35 girls (38.9 %). At the formative stage of the experiment, the control group consisted of 83 students, including 44 boys (53 %) and 39 girls (47 %); the experimental group consisted of 90 students, including 49 boys (54.4 %) and 41 girls (45.6 %).

Research Design

The pedagogical experiment was conducted in stages from 2019 to 2024 in accordance with recommendations (Sysoieva, Krystopchuk, 2013). At the ascertaining stage, future specialists in physical culture and sports were tested to determine their initial readiness level for sustainable development. At the formative stage, a methodological training system was introduced for the participants of the experimental group. At the end of the experiment, the level of readiness of the participants for educational activities related to sustainable development was determined. The methods used in the study are: study and analysis of scientific and methodological literature, pedagogical experiments, surveys, testing, analyses, synthesis and generalisation of information and methods of mathematical statistics.

For the final check of the formation of the practical component of future physical education and sports specialists' readiness for educational activities for sustainable development, thematic tests with open-ended questions were used, which allowed for a creative approach to the tasks; they were created using the Google Forms service. The questions in the tests corresponded to the material proposed for study during the acquaintance of students with the materials of the author's course "Sustainable Development in Physical Education and Sport" (Tsyhura & Harkusha, 2024) and indicators of readiness of the practical component. In particular, the tests contained questions related to methodological work in the following categories: extracurricular and community activities, leadership positions, physical education classes, and sports sections.

Accordingly, the indicators of the practical readiness criterion were defined as follows:

- activities for sustainable development at physical education lessons or sectional lessons in sport;
- activities for sustainable development during extracurricular work of a physical education teacher or during sectional work of a sports coach with a population of different age categories;
- activities for sustainable development in a managerial position.

The tests in Google Forms were distributed through Google classroom, also contained all the educational and methodological information on the course "Sustainable Development in Physical Education and Sports". The formation of the practical component of the readiness of future specialists in physical culture and sports for educational activities for sustainable development was assessed by converting the scores obtained by students into the ECTS scale for assessing the quality of educational achievements of students of higher education institutions: 0-59 points – low level, 60-74 points – satisfactory level, 75-89 points – average level, 90-100 points – high level. The same scale was used to assess each indicator (content component) of the practical component.

Statistical Analysis

Systematisation of the materials and mathematical processing were performed using a Microsoft® Excel 2010. The non-parametric Pearson's χ^2 test was used to compare the results of the study at a significance level of $p < 0.05$ (Herych & Syniavska, 2021).

Results

According to the results of the baseline testing at the formative stage of the experiment (Fig. 1, Fig. 2, Fig. 3), a significant number of students in both groups had a low level of formation in the practical component according to all the defined indicators. Thus, depending on the studied component, in the control group at the beginning of the pedagogical experiment, 88.9 % to 95.6 % of students had a low level of formation in the practical component of readiness for educational activities for sustainable development. A satisfactory level of this indicator was observed in 3.3 % of students using the indicator "activities for sustainable development in a managerial position" (Fig. 3), 2.2 % of students using the indicator "activities for sustainable development in a physical education lesson or sectional sport lesson"(Fig. 1), and 10 % of students using the indicator "activities for sustainable development during extracurricular work of a physical education teacher or outside the sectional work of a sports coach with the population of different age categories" (Fig. 2). From 1.1 % to 2.2 %, students had an

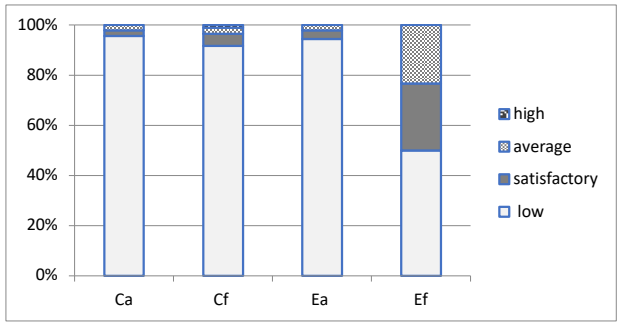

Fig. 1. Diagram of the levels of formation of the practical component of future physical education and sports specialists' readiness for educational activities for sustainable development according to the indicator "activities for sustainable development in physical education class or sectional sport lesson" (% of students): Ca – control group, ascertaining stage of the experiment; Cf – control group, formative stage of the experiment; Ea – experimental group, ascertaining stage of the experiment; Ef – experimental group, formative stage of the experiment. Similar designations are used in the rest of the diagrams

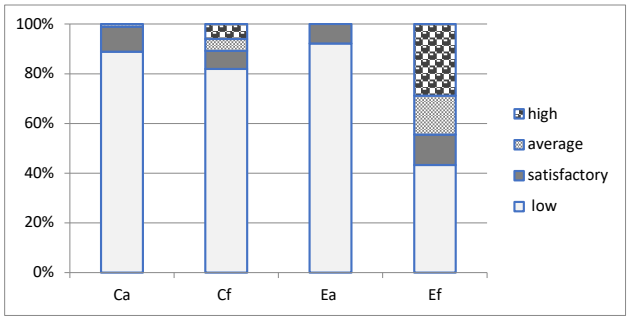

Fig. 2 Diagram of the levels of formation of the practical component of future physical education and sports specialists' readiness for educational activities for sustainable development according to the indicator "activities for sustainable development during extracurricular work of a physical education teacher or outside the sectional work of a sports coach with the population of different age groups" (% of students)

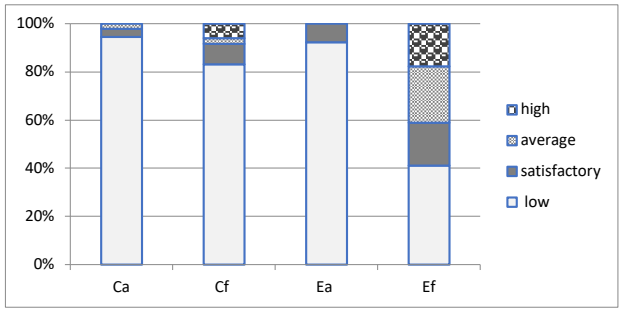

Fig. 3. Diagram of the levels of formation of the practical component of future physical culture and sports specialists' readiness for educational activities for sustainable development using the indicator "activities for sustainable development in a managerial position" (% of students)

average level of the practical component of readiness for educational activities for sustainable development, depending on the component under study (Fig. 1, 2, 3).

In the experimental group, at the beginning of the study, the situation was similar: from 92.2 % to 94.5 % of students had a low level of the practical component of readiness for educational activities for sustainable development, depending on the component under study (Fig. 1, 2, 3). From 3.3 % to 7.8 %, students had a satisfactory level of this indicator; the average level was found in 2.2 % of students only for the indicator "activities for sustainable development in physical education classes or sectional sports lessons". There were no students with a high level of formation for the studied component by any of the identified indicators in either the experimental or control groups.

At the formative stage of the pedagogical experiment, the situation in the control group underwent minor changes. In the experimental group, significant changes were observed depending on the indicator. Thus, the number of students with a low level of formation in the practical component of readiness for educational activities for sustainable development according to various indicators decreased to 41.1-50.0 %. The number of students with a high level of formation in the studied component according to the indicator "activities for sustainable development in a managerial position" is 17.8 % (Fig. 3), whereas the indicator "activities for sustainable development during the extracurricular work of a physical education teacher or out of sectional work of a sports coach with the population of different age categories" – 28.9 % (Fig. 2). The number of students with an average level of formation for the studied component according to the same indicators was 23.3 % and 15.6 %, respectively; with a satisfactory level of formation of 17.8 % and 12.2 %, respectively. For the indicator "activities for sustainable development in a physical education lesson or sectional sport lesson", the indicators are somewhat lower. There were no students with a high level of formation in the studied component. The percentage of students with a satisfactory and average level was almost the same at 26.7 % and 23.3 %, respectively (Fig. 1).

The generalised data show that at the beginning of the study, the majority of students in the control and experimental groups had a low level of the practical component of readiness for educational activities for sustainable development: 93.33 % and 94.44 % of students, respectively; 6.67 % and 5.56 % of students in the control and experimental groups had a satisfactory level of this component, respectively (Fig. 4).

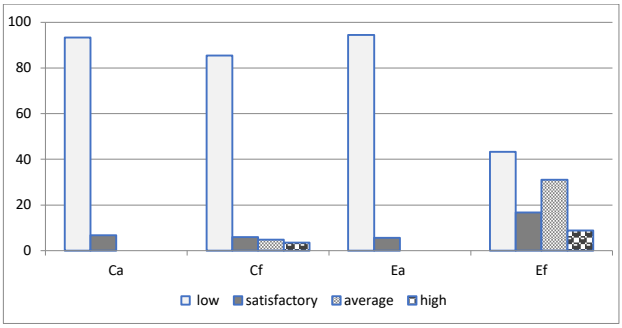

Fig. 4. Diagram of the levels of formation of the practical component of future physical education and sport specialists' readiness for educational activities for sustainable development (% of students)

The analysis of the data of the final test at the end of the formative stage of the experiment revealed a significant improvement in the indicator of the practical component of future specialists' physical culture and sports readiness for educational activities for sustainable development in the experimental group (Fig. 4). In particular, in the control group, 85.54 % of students had a low level, 6.02 % had a satisfactory level, 4.82 % had a medium level, and 3.61 % had a high level of the practical component of readiness. The number of students in the experimental group with a low level of the practical component of readiness was found to be half as much – 43.33 %, with a satisfactory level of readiness –16.67 %, with an average level – 31.11 %; and 8.89 % of respondents had a high level of the practical component of readiness for educational activities for sustainable development (Fig. 4).

The above comparisons are due to the calculation of Pearson's criterion, which was used to determine the differences between the series of indicators in our two samples (Table 1). Thus, the indicators of Pearson's criterion indicate the similarity of the control and experimental

Table 1. Distribution of students by levels of formation of the practical component of educational readiness for sustainable development (generalised data by identified components)

Groups of students	Levels of formation of the practical component of readiness				χ^2 empirical	χ^2 critical $p < 0.05$
	low	satisfactory	average	average		
Ascertaining stage of the experiment						
Control	84	6	0	0	0.096	3.84
Experimental	85	5	0	0		
Formative stage of the experiment						
Control	71	5	4	3	34.42	5.99
Experimental	39	15	28	8		

groups in terms of the level of formation of the practical component of readiness for educational activities for sustainable development at the beginning of the pedagogical experiment: χ^2 empirical < χ^2 critical (0.096 < 3.84, $p < 0.05$); and a significant difference between these groups after the formative stage of the experiment: χ^2 empirical > χ^2 critical (34.42 > 5.99, $p < 0.05$).

Discussion

According to previous studies (Tsyhura & Harkusha, 2023), it was assumed that future physical education and sports specialists have a low level of formation in the practical component of readiness for educational activities for sustainable development. The assumptions were confirmed during the ascertaining stage of the pedagogical experiment. It was found that, on average, 93.89 % of students participating in the experiment had a low level of formation in the practical component of readiness for educational activities for sustainable development. Analysing the students' answers to the questions related to sustainable development activities in physical education classes or sectional sports lessons, during extracurricular activities and community work, and while working in leadership positions in their speciality, it can be confidently stated that the vast majority of students in the control and experimental groups had no idea about the types of sustainable development activities of a physical education teacher or coach. Such results of the study are in line with the research of our foreign colleagues who indicated that it is very difficult for physical education and sports teachers to determine the types of activities for sustainable development during their professional activities (Baena-Morales et al., 2022; Merma-Molina et al., 2023).

The peculiarities of the formation of the practical component of future physical culture and sports specialists' readiness for educational activities for sustainable development were identified by analysing the levels of formation of the studied component according to pre-established indicators. Some of our results agree with those of our foreign colleagues (Baena-Morales et al., 2022; Merma-Molina et al., 2023). Thus, no students in the experimental group with a high level of formation in the practical component according to the indicator "activities for sustainable development in physical education lessons or sectional sports lessons" were found. According to the other two indicators ("activities for sustainable development during extracurricular work of a physical education teacher or outside the sectional work of a sports coach with the population of different age groups" and "activities for sustainable development in a managerial position"), an average of 23.34 % of students had a high level of formation in the practical component. This indicates that it is easier for future physical education and sports professionals to find and implement sustainable development activities during extracurricular activities, such as hiking, health days, and recreational activities, than to implement such activities in physical education classes. The ability to introduce different active sustainability activities in physical education classes while maintaining the structure of the lesson or sports training was the most difficult task of all the tasks. Imagining themselves in a leadership position or participating in extracurricular activities makes it much easier for students to find the right types and forms of work to promote sustainable development.

The positive dynamics of changes in the same indicators of the practical component of readiness in the control group of students can be explained by the fact that information about conscious citizens with developed sustainability skills from sports arenas sometimes gets into Ukrainian media and social networks. This is admired by spectators and has great educational value. An example of this is the cleaning of stands by Japanese fans after a football match in Qatar (FIFA, 2022). Accordingly, foreign colleagues point out that sustainable development education is a complex process and that extracurricular activities may have greater potential to address a variety of topics, address different age groups, and provide more opportunities for multidimensional learning experiences (Leal Filho et al., 2021). Teachers find it difficult to incorporate the provisions of sustainable development into physical education lessons due to a lack of guidance and teaching materials (Baena-Morales et al., 2022; Merma-Molina et al., 2023). However, when sustainability activities are well selected in physical education and sport classes, very positive feedback from communities and the desire of participants to continue such activities are reported (Lynch & Boylan, 2016).

Conclusions

The results of the pedagogical experiment confirm the positive impact of the experimental methodological system on the formation of the practical component of future physical education and sport specialists' readiness to participate in educational activities for sustainable development. At the beginning of the study, 93.33 % of students in the control group and 94.44 % of students in the experimental group

had a low level of the practical component of readiness for sustainable development-related educational activities. The final test showed a significant improvement in the studied indicator in the experimental group: 43.33 % of students had a low level of formation of the practical component of the studied readiness, 16.67 % had a satisfactory level, 31.11 % had an average level, and 8.89 % had a high level. The corresponding changes were observed in all defined indicators: activities for sustainable development in physical education classes or sectional sports lessons; activities for sustainable development during extracurricular work of a physical education teacher or outside the sectional work of a sports coach with a population of different age groups; and activities for sustainable development in managerial positions. In the control group, at the end of the experiment, no significant changes were found in the levels of the practical component of future physical education and sports specialists' readiness to participate in educational activities for sustainable development.

Conflict of interest

The authors declare that there is no conflict of interest.

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Діагностика рівня сформованості практичного компонента готовності майбутніх фахівців фізичної культури і спорту до освітньої діяльності для сталого розвитку

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 1 табл., 4 рис., 34 джерела.

Історія питання. Підтримка Україною стратегії сталого розвитку та євроінтеграційні процеси вимагають підготовки фахівців до освітньої діяльності для сталого розвитку.

Мета дослідження. Метою дослідження є: показати вплив впровадженої експериментальної методичної системи на формування практичного компонента готовності майбутніх фахівців фізичної культури і спорту до освітньої діяльності для сталого розвитку.

Матеріали та методи. У дослідженні брали участь 390 студентів факультетів фізичного виховання Національного університету «Чернігівський колегіум» імені Т. Г. Шевченка, Національного університету біоресурсів і природокористування України, Сумського державного університету та Сумського державного педагогічного університету імені А. С. Макаренка – майбутні фахівці фізичної культури і спорту. Студенти були інформовані про всі особливості дослідження і брали участь у педагогічному експерименті добровільно. Учасники дослідження представлені обома статями різних курсів, з яких було сформовано контрольну та експериментальну групи. Методи дослідження: вивчення та аналіз наукової та науково-методичної літератури, педагогічний експеримент, опитування, тестування, аналіз, синтез та узагальнення інформації, методи математичної статистики.

Результати. На початку дослідження 93,33 % студентів контрольної групи та 92,22 % студентів експериментальної групи мали низький рівень практичного компонента готовності до освітньої діяльності для сталого розвитку. Завершальний етап дослідження показав істотне покращення досліджуваного показника в експериментальній групі: студентів з низьким рівнем сформованості практичного компонента досліджуваної готовності було 41,12 %, із задовільним – 14,44 %, із середнім – 30,00 %, з високим – 14,44 %. Відповідні зміни простежували за усіма визначеними показниками: діяльність для сталого розвитку на уроці фізичної культури або секційному занятті з виду спорту; діяльність для сталого розвитку під час позакласної роботи учителя фізичної культури чи поза секційної роботи тренера з виду спорту з населенням різних вікових категорій; діяльність для сталого розвитку на керівній посаді. У контрольній групі на завершення експерименту істотних змін щодо рівнів практичного компонента готовності майбутніх фахівців фізичної культури і спорту до освітньої діяльності для сталого розвитку не виявлено.

Висновки. Результати педагогічного експерименту підтверджують позитивний вплив розробленої методичної системи на формування практичного компонента готовності майбутніх фахівців фізичної культури і спорту до освітньої діяльності для сталого розвитку.

Ключові слова: сталий розвиток, освіта, фізична культура, спорт, вчитель фізичної культури, тренер.

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Cite this article as: Tsyhura, H., & Harkusha, S. (2024). Diagnostics of the Level of Formation of The Practical Component of Future Physical Education and Sports Specialists' Readiness for Educational Activities for Sustainable Development. *Physical Education Theory and Methodology, 24*(5), 689-696. https://doi.org/10.17309/tmfv.2024.5.02

Received: 10.08.2024. Accepted: 11.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fizičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Optimizing the Speed and Explosive Power Performance of Football Players: The Effect of a Six-Week Neuromuscular Training

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Accepted for Publication: September 9, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.03

Abstract

Background. Football players require high levels of speed and explosive power to perform effectively on the field, making these physical attributes critical for success. Neuromuscular training has been proposed as a method to enhance these performance metrics.

Objectives. The purpose of the present study was to examine the effect of neuromuscular training on the speed and explosive power performance of football players.

Materials and methods. A total of thirty male football players (aged 20 to 26 years) from Imphal West District, Imphal, Manipur, India, who had participated in national-level competitions, were selected for the study. The subjects were randomly assigned into two equal groups: an experimental group (n = 15) and a control group (n = 15). Both groups were assessed before the intervention for speed and explosive power performance using the 50 m dash speed test and the standing broad jump test to determine the baseline significance of the selected variables. Following the initial assessments, the experimental group underwent a supervised neuromuscular training program, while the control group received no special training. The neuromuscular training was conducted over a period of six weeks, with sessions held five days a week (Monday to Friday), each lasting 60 minutes.

Results. The experimental group confirmed significant improvements in both speed and explosive power compared to the control group ($p < 0.05$). The mean and standard deviation of speed for the experimental group were 7.15 ± 0.71 in the pre-test and 6.54 ± 0.61 in the post-test. For explosive power, the values were 2.36 ± 0.32 in the pre-test and 2.55 ± 0.39 in the post-test. The notable enhancements in speed and explosive power performance in the experimental group are likely attributed to the six-week neuromuscular training program, which facilitated rapid physical adaptation among the football players.

Conclusions. Implementing the six-week neuromuscular training program effectively enhanced the speed and explosive power performance of football players. This type of training has been demonstrated to be highly effective for optimizing these performance metrics in football players.

Keywords: neuromuscular training, speed performance, explosive power performance, physical adaptation.

Introduction

Football is the most popular ball game globally, enjoyed by players and spectators alike, with millions watching soccer matches and its popularity growing daily (Islam & Rahman, 2021). The game involves two teams of eleven players each trying to score by kicking the ball into the opposing team's goal, using any part of their bodies except their hands and arms, with only the goalkeeper allowed to handle the ball within the penalty area (Alegi et al., 2024). Known for its fast-paced play, football's global appeal is unmatched, making it thrilling for both players and fans. The modern game emphasizes "high sports performance," highlighting skill application, technical and tactical growth, enhancement of

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key motor components, and physiological traits impacting performance. Sports scientists focus on physical and technical development as well as cognitive abilities (Mola & Shaw, 2024). Research indicates that attributes such as muscular endurance, flexibility, coordination, upper body strength, leg power, maximum leg strength, speed, agility, and reaction time are essential for football players (Singh et al., 2018; Singh et al., 2016; Rahman & Sharma, 2023).

Neuromuscular training encompasses a range of activities aimed at enhancing motor sensory function during physical performance in various sports. It seeks to boost muscle motor efficiency, reduce neuromuscular fatigue, and improve overall fitness (Sanudo et al., 2019; Rogasch et al., 2009). Studies show that this training can improve the neurological system's response to the muscular system, enhancing muscle recruitment and activation, which in turn increases athlete compatibility and strength (Akbar et al., 2022). While match-play scenarios requiring maximum running speeds are rare, a player's top running speed during a game is a common measure of physical ability, with professional footballers typically reaching peak sprinting speeds of 31-32 km/h (Rampinini et al., 2007).

Explosive strength and power are essential for athletic performance and are the foundation combined with game-specific techniques, tactics, and daily activities (Heang et al., 2012; Reza et al., 2024). Developing maximum strength performance is critical as it supports most other aspects of physical ability. Lower body training typically includes exercises such as jumping, hopping, and bounding. Plyometric exercises, involving jumping, hopping, and skipping, are fundamental to many sports movements (De Villarreal et al., 2010). The systematic development and assessment of these skills can be challenging. Strength and speed training can improve teenagers' muscular and neurological reaction rates, strength, and explosiveness. These exercises can also be used to evaluate their impact on football performance (Barrera et al., 2023). Therefore, this study aims to examine the effect of neuromuscular training on the speed and explosive power performance of football players.

Materials and Methods

Selection of Subjects

In this study, the researcher randomly chose 30 male football players, aged between 20 and 26, from Imphal West District in Imphal, Manipur, all of whom had competed at the national level.

Selection of Variables

After assessing the feasibility of the equipment and reviewing the relevant literature, the researcher identified the following variables:

1. Independent Variable: Neuromuscular Training.
2. Dependent Variables: Speed and Explosive Power.

Criterion Measures

The study utilized the following standardized tests:

1. Speed: Assessed with the 50-meter dash test, with times recorded in seconds.
2. Explosive Power: Evaluated using the standing broad jump test, with distances measured in meters.

Design of the Study

In this experimental study, participants were randomly divided into two equal groups: an experimental group (n = 15) and a control group (n = 15). Both groups were evaluated before the intervention to establish baseline measurements for speed and explosive power using the 50-meter dash test and the standing broad jump test. After these initial assessments, the experimental group underwent a supervised neuromuscular training program, while the control group did not receive any specialized training. The neuromuscular training program spanned six weeks, with sessions conducted five days a week (Monday to Friday). Each session lasted 60 minutes, with weekends reserved as rest days.

Administration of Training

To fine-tune the volume and intensity of the exercise, a pilot study was carried out with 8 football players, split into

Table 1. Six-weeks neuromuscular training program

Days	Warm-Up	Particular Exercise	Sets	Reps	Intensity	Rest
Mon	Slow Jogging, Free hand Exercise, Whole Body rotation and Stretching	Squat Jump, Push Up Lateral Jump, High Knee forward Run, Shuttle Run, Burpee	2	8	30-40 %	30 sec
Tue	Slow Jogging, Free hand Exercise, Whole Body rotation and Stretching	Push up, Pull up, Jump squats Plank, Sit ups, Split squad	3	10	40-50 %	30 sec
Wed	Slow Jogging, Free hand Exercise, Whole Body rotation and Stretching	10 m running, 30 m running 50 m running, Single leg Hop Box Jump	4	12	50-60 %	30 sec
Thu	Slow Jogging, Free hand Exercise, Whole Body rotation and Stretching	Squat Jump, Push Up Lateral Jump, High Knee forward Run, Shuttle Run, Burpee	5	14	60-70 %	30 sec
Fri	Slow Jogging, Free hand Exercise, Whole Body rotation and Stretching	10m running, 30 m running 50 m running, Single leg Hop Box Jump	6	16	70-80 %	30 sec

Note: The neuromuscular training program was conducted over six weeks, with sessions held five days a week (Monday to Friday). Each session lasted 60 minutes, with rest days on Saturday and Sunday

4 in the experimental group and 4 in the control group. Notable differences were found between the pre-test and post-test measurements of the variables. Subsequently, the refined training sessions for the experimental group were conducted in the mornings at the Manipur University Football Ground. The neuromuscular training program lasted six weeks, with sessions held five days a week (Monday to Friday). Each session lasted 60 minutes, with Saturday and Sunday as rest days. Details of the specific neuromuscular training program for the experimental group are provided in Table 1.

Statistical Analysis

Data were entered into an Excel spreadsheet and analyzed using IBM SPSS software (version 22.0; SPSS Inc., Chicago, IL, USA). The normality of the statistical distribution was assessed through descriptive statistics. To evaluate differences between groups, paired t-tests and ANCOVA were utilized. A significance level of 0.05 was applied in the statistical analyses.

Ethical Approval

The study received approval from the Institutional Human Ethics Committee at Manipur University, Canchipur, Imphal (India), and informed consent was obtained from all participants.

Results

The results indicated a significant enhancement in speed performance among football players in the experimental group who underwent the neuromuscular training program. The descriptive analysis of the pre-test and post-test speed performance for this group is detailed in Table 2.

Table 2 displays the mean and standard deviation of speed for both the experimental and control groups in the pre-test and post-test assessments. For the experimental group, the pre-test mean and standard deviation were 7.15 ± 0.71, while the post-test mean and standard deviation were 6.79 ± 0.61. In the control group, the pre-test values were 7.05 ± 0.54, and the post-test values were 7.00 ± 0.53. A significant improvement was observed in the experimental group, with a calculated t-value of 6.06, exceeding the table t-value of 2.14 at 14 degrees of freedom and a 0.05 level of significance. Conversely, the control group showed no significant change, as its calculated t-value of 0.71 was lower than the table t-value of 2.14 at 14 degrees of freedom and a 0.05 level of significance. Figure 1 provides a graphical comparison of the pre-test and post-test mean speed performance for both groups.

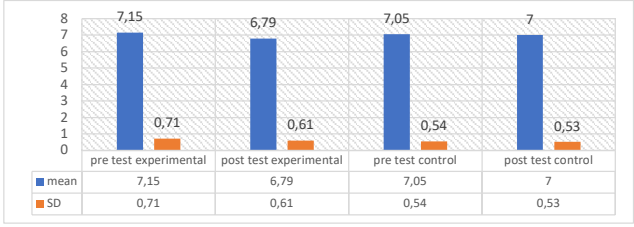

Fig. 1. Graphical comparison of pre-test and post-test speed performance for experimental and control groups

The study results revealed a significant enhancement in explosive power performance among football players in the experimental group following the neuromuscular training program. Table 3 provides a descriptive analysis of the pre-test and post-test explosive power performance for this group.

Table 4 shows the mean and standard deviation for explosive power in both the experimental and control groups during pre-test and post-test assessments. For the experimental group, the pre-test mean and standard deviation were 2.36 ± 0.32, and the post-test mean and standard deviation were 2.55 ± 0.29. In the control group, the pre-test values were 2.35 ± 0.25, while the post-test values were 2.32 ± 0.20. A significant improvement was observed in the experimental group, with a calculated t-value of 1.64 surpassing the table t-value of 2.14 at 14 degrees of freedom and a 0.05 significance level. Conversely, the control group

Table 2. Pre-test and post-test mean for experimental and control groups of speed performance of football players

Variable	Group	N	Test	M	SD	SEM	df	t-value	Sig.
Speed	Experimental	15	Pre-test	7.15	0.71	0.18	14	6.06*	0.00*
			Post-test	6.79	0.61	0.15			
	Control	15	Pre-test	7.05	0.54	0.13		0.71	0.48
			Post-test	7.00	0.53	0.13			

*Significant at 0.05 level

Table 3. Mean pre-test and post-test explosive power performance for experimental and control groups

Variable	Group	N	Test	M	SD	SEM	df	t-value	Sig.
Explosive Power	Experimental	15	Pre-test	2.36	0.32	0.08	14	9.11*	0.00*
			Post-test	2.55	0.29	0.07			
	Control	15	Pre-test	2.35	0.25	0.06		1.64	0.12
			Post-test	2.32	0.20	0.05			

*Significant at 0.05 level

did not show a significant change in explosive power, as its calculated t-value of 1.64 was lower than the table t-value of 2.14 at 14 degrees of freedom and a 0.05 level of confidence. Figure 2 illustrates the graphical comparison of pre-test and post-test mean explosive power for both groups.

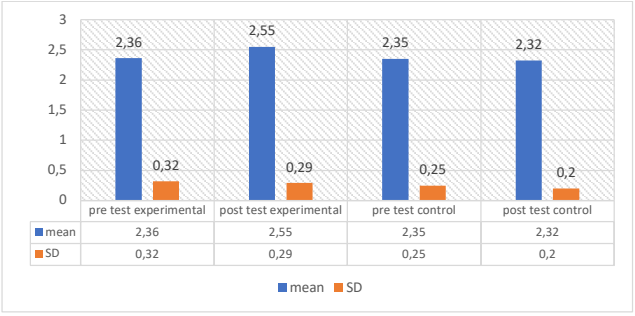

Fig. 2. Graphical representation of pre-test and post-test mean comparisons for speed performance in the experimental and control groups

Table 4. Pre and Post mean comparison (ANCOVA) between experimental and control group for speed of football players

Variable	Source	Type III sum of errors	df	Mean Square	F	Sig.
Speed	Group	0.63	1	0.63	12.46*	0.00
	Error	1.38	27	0.51		
	Total	1438.24	30			

* Significant difference at 0.05 level

Table 4 shows a significant difference between the pre-test and post-test mean scores for speed performance in both the experimental and control groups, as determined by analysis of covariance (ANCOVA). The obtained F-value of 12.46* was higher than the tabulated F-value of 4.21, confirming the effectiveness of the six-week neuromuscular training program in enhancing football players' speed performance. Table 5 presents the ANCOVA results for pre-test and post-test explosive power between the experimental and control groups.

Table 5. Pre and post mean comparison (ANCOVA) between experimental and control group for explosive power of football players

Variable	Source	Type III sum of errors	df	Mean Square	F	Sig.
Explosive Power	Group	0.37	1	0.37	10.35*	0.00
	Error	0.10	27	0.00		
	Total	181.13	30			

* Significant difference at 0.05 level

Table 5 indicates a significant difference between the pre-test and post-test mean scores for explosive power in both the experimental and control groups, as determined by analysis of covariance (ANCOVA). The obtained F-value of 10.35* exceeded the tabulated F-value of 4.21, confirming that the six-week neuromuscular training program effectively improved explosive power performance in football players.

Discussion

The study aimed to examine the impact of neuromuscular training on speed and explosive power in football players. Thirty national-level players from Manipur University, aged 20 to 26, were randomly assigned to either an Experimental Group or a Control Group, with 15 players in each group. The Experimental Group participated in a six-week neuromuscular training program at Manipur University Football Ground, with sessions held five days a week. Post-test data were collected and analyzed using IBM SPSS (version 22.0). Statistical analyses, including paired t-tests and ANCOVA, were performed with a significance level set at 0.05.

Based on the results, Table 2 displays the mean and standard deviation values for speed in both the experimental and control groups during pre-test and post-test assessments. Significant improvements were observed in the experimental group, while the control group showed no notable changes. Table 3 presents mean and standard deviation values for explosive power, with significant gains in the experimental group and no significant changes in the control group. Table 4 demonstrates a significant difference in speed performance between pre-test and post-test scores for both groups, confirmed by ANCOVA, indicating that the six-week neuromuscular training program effectively enhanced speed. Similarly, Table 5 shows a significant difference in explosive power performance between pre-test and post-test scores for both groups, also confirmed by ANCOVA, confirming the effectiveness of the training program in improving explosive power. Singh et al. (2023) investigated the impact of a six-week Speed, Agility, and Quickness (SAQ) training program on 30 male football players aged 18-25. The study found that the SAQ program significantly enhanced speed and agility in the experimental group compared to the control group.

Anbu et al. (2022) and Singh et al. (2022) found that neuromuscular and plyometric training enhanced agility, speed, and explosive power in young football players. Singh and Lamani (2016) discovered that varying training loads improved physical and physiological variables in male soccer players. Mola & Bayeta (2020) confirmed that circuit training increased muscular endurance, strength, and flexibility in sport science students. Fenta & Mola (2023) demonstrated that calisthenics exercises effectively improved passing accuracy, dribbling speed, agility, and muscular strength in female handball players. Menezes et al. (2020) showed that integrative neuromuscular training improved balance, flexibility, and vertical jump height in young soccer players. These studies collectively highlight the significance of implementing well-structured, scientifically-supported training programs to boost athletic performance across different sports and age groups.

Recent research underscores the effectiveness of plyometric and speed-strength training in enhancing various physical attributes in soccer players. Kokinda et al. (2023) showed that plyometric training improves running speed, acceleration, and directional changes. Similarly, Feng Gao (2023) found that speed and strength exercises

enhance running speed, muscular explosive force, and agility. Justin Antony (2023) assessed a 6-week plyometric program in football players aged 16-19 and noted significant improvements in speed, though agility did not show notable changes. These results suggest that while plyometric training is effective for boosting speed, its impact on agility is less clear, highlighting the need for further research in this area.

Sannicandro et al. (2023) demonstrated the effectiveness of integrative neuromuscular pitch training in improving lower limb strength and sprint performance in young soccer players. Buchheit et al. (2010) found that a 10-week program incorporating shuttle sprints and explosive strength training improved 30-meter sprint times, although results for shorter distances were mixed in adolescent male soccer players. Hughes et al. (2012) reported enhanced sprint performance in certain age groups through combined speed and plyometric training. Carlos Álvarez-Serrano et al. (2023) highlighted the role of neuromuscular training in reducing injury risk and potentially enhancing various physical performance factors such as strength, power, speed, agility, and balance in soccer players. These studies collectively emphasize different strategies for improving soccer performance and injury prevention through targeted training approaches.

Conclusion

Based on the study results, it can be concluded that neuromuscular training significantly improves the speed and explosive power of football players. The six-week neuromuscular training program resulted in substantial gains in these areas. Consequently, incorporating such a program is highly advantageous for boosting athletic performance in football players. This training regimen effectively develops essential physical attributes like speed and explosive power, making it a valuable addition to training protocols for players seeking to enhance their overall on-field performance.

Acknowledgment

The author extends heartfelt gratitude to the football players for their collaboration, assistance, and positive contributions. Special thanks are also due to the co-authors for their valuable help in finalizing the text. Best wishes are sent to everyone who supported this project, both directly and indirectly.

Conflict of Interest

The authors and participants in these studies declared no conflicts of interest.

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Оптимізація показників швидкості та вибухової сили футболістів: Вплив шеститижневого курсу нервово-м'язового тренування

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 5 табл., 2 рис., 27 джерел.

Історія питання. Для ефективної гри на полі футболісти потребують високого рівня швидкості та вибухової сили, зумовлюючи критичну важливість цих фізичних якостей у досягненні успіху. В якості методу покращення цих показників запропоновано проведення нервово-м'язових тренувань.

Мета дослідження. Метою цього дослідження було вивчити вплив нервово-м'язового тренування на показники швидкості та вибухової сили футболістів.

Матеріали та методи. Для проведення дослідження було відібрано тридцять футболістів-чоловіків (віком від 20 до 26 років) із Західного округу Імпхал (штат Маніпур, Індія), які брали участь у змаганнях національного рівня. Досліджувані були розподілені методом рандомізації на дві рівні групи: експериментальну (n = 15) та контрольну (n = 15). Перед початком інтервенції в обох групах оцінювали показники швидкості та вибухової сили, застосовуючи тест на швидкість бігу на дистанції 50 метрів, а також тест з виконання стрибків у довжину з місця з метою визначення вихідного рівня значущості відібраних змінних. Після проведення початкового аналізу експериментальна група виконувала контрольовану програму з нервово-м'язового тренування, тоді як контрольна група не займалася жодним спеціальним тренуванням. Нервово-м'язові тренування проводилися впродовж періоду шести тижнів, заняття проходили п'ять днів на тиждень (з понеділка по п'ятницю), з тривалістю 60 хвилин кожне.

Результати. В учасників експериментальної групи спостерігалося достовірне покращення показників як швидкості, так і вибухової сили порівняно з контрольною групою ($p < 0,05$). Середні значення та стандартне відхилення швидкості в експериментальній групі становили 7,15 ± 0,71 перед початком проведення тесту та 6,54 ± 0,61 після його завершення. Для вибухової сили ці показники становили 2,36 ± 0,32 на етапі передтестового дослідження та 2,55 ± 0,39 — на етапі післятестового періоду. Суттєве покращення показників швидкості та вибухової сили в експериментальній групі, ймовірно, пов'язане з проведенням шеститижневої програми нервово-м'язових тренувань, яка сприяла швидкій фізичній адаптації футболістів.

Висновки. Реалізація шеститижневої програми нервово-м'язових тренувань сприяла ефективному поліпшенню показників швидкості та вибухової сили футболістів. Доведено, що такий тип тренувань є високоефективним методом оптимізації зазначених показників у футболістів.

Ключові слова: нервово-м'язове тренування, показники швидкості, показники вибухової сили, фізична адаптація.

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Cite this article as: Singh, L. S., Singh, N. R., Singh, W. J., Singh, O. R., & Mola, D. W. (2024). Optimizing the Speed and Explosive Power Performance of Football Players: The Effect of a Six-Week Neuromuscular Training. *Physical Education Theory and Methodology, 24*(5), 697-703. https://doi.org/10.17309/tmfv.2024.5.03

Received: 24.07.2024. Accepted: 09.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Physiological Response to Speed Endurance Soccer Training in Amateur Players

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Accepted for Publication: September 9, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.04

Abstract

Objectives. This study aimed to examine the physiological response to speed endurance soccer training (SEST), which involved the measurement of heart rate (HR), blood lactate (LAC), and blood pressure (BP) are measured during the four-week intervention period.

Materials and methods. The one-group pretest-posttest pre-experimental design was used in this study. The study comprised 15 male amateur soccer players with an average age of 16.13 ± 0.52 years. The participants' mean height was 167.4 ± 4.63 cm, weight was 57.69 ± 12.11 kg, and BMI was 20.44 ± 3.45 kg/m^2. The data findings are presented using the mean and standard deviation. The paired t-test was employed to assess the impact of each group. The threshold for statistical significance was set at a p-value of less than 0.05. The effect size (ES) was calculated using Cohen's ES as a metric to quantify the magnitude of the difference between the pretest and posttest stages.

Results. The HR results monitoring during the intervention period were in the high-intensity zone, with an average of 91.67 ± 0.6 % and a HR of 187.67 ± 1.24 bpm. No significant change was observed in the heart rate response from baseline to end of intervention. The LAC results showed that the lactate level was in the high category, namely an average of 11.03 ± 1.3 mmol·L^{-1}. BP indicated a significant difference between pretest and posttest ($p \leq 0.05$). The systolic blood pressure (SBP) demonstrated an increase of Δ % = 0.95, while the diastolic blood pressure (DBP) showed an increase of Δ % = 1.39.

Conclusions. The findings of this study indicate that SEST has a notable effect on the body's physiological functions, namely on the cardiovascular system, anaerobic metabolism, and blood pressure. This effect was observed over a period of four weeks in amateur soccer players.

Keywords: blood lactate, blood pressure, heart rate, speed endurance soccer training.

Introduction

The progress of soccer places a greater demand on players, especially in their capacity to handle the escalating intensity of matches, both with and without possession of the ball (Barnes et al., 2014; Bush et al., 2015; Nassis et al., 2020). Consistent with prior studies, it has been determined that soccer is a sport that requires high levels of physical exertion. The average heart rate during a soccer game reaches 85 % of the maximum heart rate, and it is possible to attain an intensity of 90-95 % of the maximum heart rate (Mendez-Villanueva et al., 2013; Rebelo et al., 2014). To meet the high physical demands in soccer, physical training alone is insufficient; a combination with tactical training is also necessary (Kusuma, Kusnanik, Lumintuarso, & Phanpheng, 2024). Recent research has identified a holistic training method known as Speed Endurance Soccer Training (SEST), which has been proven to enhance the abilities of soccer players (Kusuma, Kusnanik, Lumintuarso, Setijono, et al.,

© Kusuma, I. D. M. A. W., Kusnanik, N. W., Pramono, B. A., Pranoto, A., Phanpheng, Y., Nurpratiwi, R., Bawono, M. N., & Nurhayati, F., 2024.

2024). However, this research has limitations, particularly the lack of an in-depth study on physiological responses, such as heart rate (HR), blood lactate, and blood pressure. Understanding physiological responses is crucial to ensure that the training aligns with its objectives (Clemente et al., 2023; Dello Iacono et al., 2022; Lechner et al., 2023). These indicators are vital in determining whether the training goals are met, as they provide insight into the internal load and the body's adaptation to training. Therefore, further studies that integrate physiological aspects into the evaluation of the SEST program are essential to ensure its effectiveness and appropriateness for soccer players.

Previous research on physiological responses has been carried out but is still separated into two studies, namely HIIT and SSG (Arslan et al., 2017; Köklü & Alemdaroğlu, 2016; Kunz et al., 2019; Ouertatani et al., 2022; Radziminski et al., 2013). Studies analyzing physiological responses to the combined training concept of HIIT and SSG are still very limited. Previous research has analyzed heart rate and blood lactate responses to SSG training combined with running training, but this study did not analyze blood pressure variables (Köklü et al., 2020). Physiological responses that can be monitored from the exercise process are blood lactate (LAC), heart rate (HR), and systolic and diastolic blood pressures (SBP and DBP) (D. M. Forte et al., 2022; Köklü et al., 2017). By knowing the lactate level in the blood, you will know the type of exercise a person is doing at an aerobic or anaerobic level and a person's physical fitness (Selmi et al., 2021). Meanwhile, measuring blood pressure during exercise can provide information about the cardiovascular response to physical activity (Arboleda-Serna et al., 2016).

Many coach, both professional and amateur, have included the SEST training idea into their programs, even if they do not openly refer to it by name. This approach incorporates both physical and tactical elements under a single training model. SEST involves various acts in soccer, including passing, dribbling, crossing, shooting, sprinting, as well as situations such as attacking, transitioning, and defending. In order to enhance physical performance, it is important to examine an individual's physiological reaction throughout the execution of this exercise. To investigate the physiological response of LAC, HR, SBP and DBP during SEST training, it is imperative to do study on this topic. It is anticipated that it can offer more reliable information in the realm of sports coaching, particularly for soccer coaches, whether they are professionals or amateurs.

Materials and Methods

Study participants

The population for this study consisted of 117 male soccer player. This study included a sample of 15 male soccer players with an average age of 16.13 ± 0.52 years. The participants had an average height of 167.4 ± 4.63 cm, weight of 57.69 ± 12.11 kg, and BMI of 20.44 ± 3.45 kg/m^2.

Study Organization

The research employed a pre-experimental procedure utilizing a one-group pretest and posttest design. Subjects were given a pretest to determine their initial HR, LAC, and BP. Next, the subject was given SEST for four weeks with a frequency of three times a week, and intensity 80-90 % HRmax. After treatment, the samples were given a posttest in the final week to determine differences in physiological responses to SEST. Apart from that, each sample training session continues to have its HR and BP monitored, while its LAC was monitored once a week. The process of gathering data involved the use of an OMRON automatic equipment (OMRON Model HEM-7130 L, Omron Co., Osaka, Japan) to measure BP. HR measurement utilizing the Polar H10 Sensor, manufactured by Polar Inc. in the United States. Concurrently, LAC levels were assessed using the Accutrend Plus Meter (Accutrend® lactate meter, Roche Diagnostics, Mannheim, Germany).

Statistical Analysis

The data is displayed in the form of the mean and standard deviation. The Shapiro-Wilk test was employed to evaluate the normality of the data. The percentage change (Δ%) between the pretest and posttest results during the training period was determined using the formula: Δ % = ((Post-Pre)/Pre)*100. A paired t-test was performed to assess the effect within each group. The threshold for statistical significance was established at a p-value of less than 0.05. Cohen's effect sizes (ES) were calculated to measure the extent of disparities between groups. A value of ES more than 0.8 was categorized as big, while a value between 0.8 and 0.5 was classified as medium. A value between 0.5 and 0.2 was considered minor, and any value below 0.2 was regarded as negligible, according to Cohen (2013).

Results

The normality test using the Shapiro-Wilk test shows that the data was normally distributed with a significance value of Sig > 0.05. Next, a paired sample t-test was carried out with the results in Table 1.

Table 1. Pretest and posttest results of SEST

Parameter	Pretest	Posttest	Δ %	p	ES
Heart Rate (bpm)	185.64 ± 6.59	186.80 ± 5.16	0.62	0.600	0.140
Heart Rate (%)	90.67 ± 3.14	91.24 ± 2.51	0.62	0.600	0.140
Lactate (mmol/L)	10.33 ± 2.31	9.87 ± 0.98	4.45	0.410	0.220
SBP (mmHg)	119.33 ± 2.97	118.20 ± 3.00	0.95	0.000*	2.190
DBP (mmHg)	76.80 ± 2.62	75.73 ± 2.46	1.39	0.000*	1.110

Description: Data are presented as mean ± SD; Δ (%): Percentage of change between pre and post-training performance; p: Level of significance; ES: Effect size; (*): Significant at pretest (p < 0.05).

Based on the research results Table 1 shows the pretest and posttest analysis data where the SBP and DBP values have a significant difference with p < 0.05, with an increase of 0.96 % in SBP and 1.39 % in DBP. Meanwhile, other parameters did not show significant differences.

Figure 1 above shows that the results of HR monitoring on SEST are in the high category where, in each training session, the average heart rate is above 90%, whereas if we look at the average for 4 weeks of training, the heart rate shows an average of 91.67 ± 0.6 %.

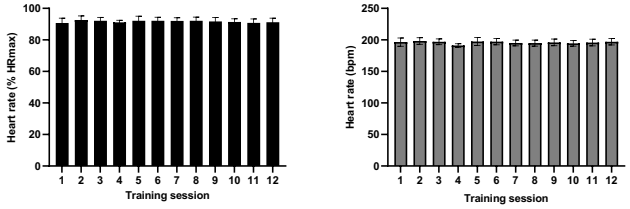

Fig. 1. HR monitoring during four weeks of SEST

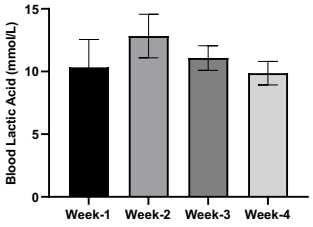

Fig. 2. LAC monitoring during four weeks of SEST

Fig. 2 above shows LAC monitoring during the four weeks of SEST. If we look at the LAC results per week, it shows that lactate was 10.33 ± 2.23 mmol/L in the first week, 12.83 ± 1.74 mmol/L in the second week, 11.08 ± 0.98 mmol/L in the third week, and 9.87 ± 0.94 mmol/L in the fourth week. Meanwhile, if we look at the total of four weeks of SEST sessions, the average LAC result was 11.03 ± 1.3 mmol/L.

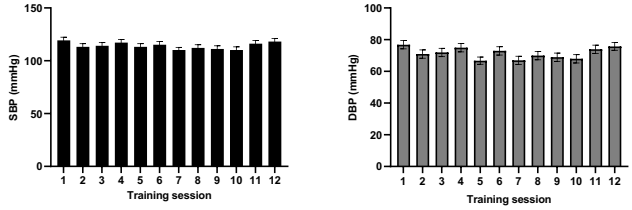

Fig. 3. BP Monitoring for four-weeks

Fig. 3 above shows the BP monitoring results for each training session for four weeks. The average SBP and DBP results for each exercise show the normal limits below 120 mmHg and 80 mmHg. If we look at the average for four weeks, it was that SBP: 114.21 ± 3.07 mmHg and DBP: 71.47 ± 3.46 mmHg.

Discussion

This study analyzes the physiological response to SEST during 4 weeks of treatment. The findings showed that the HR response during exercise entered the high-intensity zone with an average of 91.67 ± 0.6% and a heart rate of 187.67 ± 1.24 beats/min. There was no significant change in heart rate response from the start of treatment to the end. The response from lactate taken 4 times showed that the lactate level was in the high category, namely an average of 11.03 ± 1.3 mmol·L^{-1}. An interesting finding was an increase in the first 2 weeks and a relative decrease in the final 2 weeks, while blood pressure showed a significant difference between the pretest and posttest. SBP shows an increase of Δ% = 0.95, while DBP shows an increase of Δ % = 1.39.

Significant findings related to physiological responses, especially in HR levels during four weeks of SEST. Over four weeks, it was observed that the training zone was consistently in the high zone for each training session. These results align with previous research, which examined the response of SSG combined with running drill to produce a heart rate of 88.9 ± 2.5 % HRmax in the 3-a-sided model and 86.8 ± 4.0 % HRmax in the 4-a-sided (Köklü et al., 2020). Previous research also obtained similar results, namely that the HR level was in the high category (Brandes & Elvers, 2017; Halouani et al., 2017). The increase in HR occurs simultaneously with a decrease in parasympathetic stimulus and an increase in autonomic sympathetic stimulus, which during exercise is caused by proprioceptors (movement), baroreceptor reflexes (carotid dilation), and chemoreceptors (low pO_2, high pCO_2, and H+ in the bloodstream) (O'Leary, 1996). These findings indicate that SEST training consistently induces high levels of cardiovascular activity, with exercise participants' HR falling into the high category. This phenomenon can be interpreted as a physiological response that occurs due to the high intensity of the exercise. The sustained increase in HR over four weeks indicates that the exercise participants continued to experience significant cardiovascular stress, resulting in cardiac adaptation to the continuous training load. These findings provide a further understanding of the effects of SEST training on the cardiovascular system, and the implications can be used by trainers to design appropriate training programs to increase endurance (Brandes & Elvers, 2017).

This study highlights interesting findings related to physiological responses, specifically to LAC levels. In the first two weeks of SEST, a significant increase in LAC levels after the training session was found to be 12.83 ± 1.74 mmol·L^{-1}. These results are in line with previous research which examined the response of combined SSG with a running drill, which produced LAC 9.6 ± 1.9 mmol·L^{-1} in the 3-a-sided model and 8.2 ± 1.7 9 mmol·L^{-1} in 4-a-sided (Köklü et al., 2020). Previous research also obtained similar results, namely high Lactad levels (Chmura et al., 2023). Elevated lactate concentrations are believed to result from glycolytic flow rates (Gladden et al., 1995; MacRae et al., 1992). This indicates that the exercise participants experienced an increase in anaerobic metabolic rate, reflecting the high intensity of the exercise. An interesting finding in the last two weeks of the study was a tendency to decrease LAC levels after the SEST training session. Even though there was a decrease, the lactate results in the third and fourth weeks were 9.87 ± 0.94 mmol·L^{-1}. This value was still in the high category, which exceeded the lactate threshold of the lactate curve according to the Stegmann procedure (Faude et al., 2013, 2014). The decrease in lactate can be interpreted as the working of the Cori cycle in the liver. The Cori cycle refers to the metabolic pathway of lactate produced by anaerobic glycolysis in muscle cells, which is transferred to the liver and converted into glucose for eventual return to the muscles (Yang et al., 2020). Additionally, the decrease may reflect the body's adaptation to sustained exercise, where the exercise participant becomes more efficient in his metabolic processes. A decrease in LAC levels does not significantly reflect a decrease in exercise intensity or reduced physiological impact but rather indicates the body's ability to adapt to high-intensity exercise over time (Hostrup & Bangsbo, 2023).

In the Panveloski-Costa et al. (2012), the decrease in blood lactate concentration after 6 weeks of exercise was based on the effectiveness of muscle performance in storing

PCr. An increase in muscle ability to resynthesize PCr is possible because training during the first 2 weeks increases muscle function (volume and number of muscle fibers) so that a lot of PCr is stored in it after 2 weeks of training. Forbes' study also found increased PCr resthesis in thigh muscles, which also carried out high-intensity exercise for 2 weeks (Forbes et al., 2009).

The pretest and posttest results showed that SBP and DBP had significant differences. However, if seen from monitoring each exercise, there were variations in increasing and decreasing blood pressure. This study's findings align with previous research with positive results in reducing blood pressure (Carpes et al., 2022; Costa et al., 2018). However, the sample in the study was people who had hypertension. Other studies have found decreased DBP due to HIIT training (Leal et al., 2020; Way et al., 2019). Other research proves a decrease in SBP in HIIT training (Oliveira et al., 2023). Different findings from the previous study that compared the BP response in the HIIT and MICT exercise models, which resulted in a reduction in diastolic blood pressure only in the MICT model (Arboleda-Serna et al., 2019). This indicates that SEST training may have varying effects on exercise participants' blood pressure over time. These fluctuations can reflect individual responses to training intensity and the body's adaptation to changing workloads. These findings provide important insight that BP responses in the context of SEST exercise may vary, and understanding these dynamics may be an important factor in designing effective and safe exercise programs.

Conclusions

SEST produces significant physiological impacts with dynamic cardiovascular system responses, anaerobic metabolism, and blood pressure over a four-week training period. This understanding can be the basis for designing exercise programs that suit the physiological responses of exercise participants

Conflict of interest

No conflict of interest was reported by the authors.

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Фізіологічна реакція організму гравців-аматорів на тренування швидкісної витривалості у футболі

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 1 табл., 3 рис., 41 джерел.

Мета дослідження. Мета цього дослідження полягала у вивченні фізіологічної реакції на тренування швидкісної витривалості у футболі (ТШВФ), що передбачало вимірювання показників частоти серцевих скорочень (ЧСС), рівня лактату в крові (ЛАК) та артеріального тиску (АТ) протягом чотиритижневого періоду інтервенції.

Матеріали та методи. У цьому дослідженні використовувався одногруповий передтестовий та післятестовий передекспериментальний метод. У дослідженні взяли участь 15 футболістів-аматорів чоловічої статі із середнім віком 16,13 ± 0,52 року. Середній зріст учасників становив 167,4 ± 4,63 см, вага — 57,69 ± 12,11 кг, а ІМТ — 20,44 ± 3,45 кг/м2. Результати дослідження представлено із застосуванням середнього значення та стандартного відхилення. З метою оцінки ефективності впливу дослідження кожної групи використовувався парний t-критерій. Поріг статистичної значущості був встановлений на рівні p-значення менше 0,05. Розмір ефекту (ES) розраховували з використанням ES Коена як показника для кількісної оцінки величини різниці між перед- та післятестовим етапами.

Результати. Результати вимірювання показників ЧСС під час періоду інтервенції знаходилися в межах зони високого рівня інтенсивності, в середньому 91,67 ± 0,6 %, а ЧСС становила 187,67 ± 1,24 уд/хв. Значних змін у реакції ЧСС від початку до завершення інтервенції не спостерігалося. За результатами аналізу ЛАК, показник лактату в крові був у межах високого рівня, а саме становив у середньому 11,03 ± 1,3 ммоль·л-1. Рівень АТ вказував на достовірну різницю між результатами до та після проведення тесту ($p \leq 0,05$). Систолічний артеріальний тиск (САТ) збільшився на Δ % = 0,95, тоді як діастолічний артеріальний тиск (ДАТ) підвищився на Δ % = 1,39.

Висновки. Результати цього дослідження свідчать про значний вплив ТШВФ на фізіологічні функції організму, а саме на серцево-судинну систему, анаеробний метаболізм та артеріальний тиск. Даний ефект спостерігався впродовж чотиритижневого періоду у футболістів-аматорів.

Ключові слова: лактат крові, артеріальний тиск, частота серцевих скорочень, тренування швидкісної витривалості у футболі.

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Cite this article as: Kusuma, I. D. M. A. W., Kusnanik, N. W., Pramono, B. A., Pranoto, A., Phanpheng, Y., Nurpratiwi, R., Bawono, M. N., & Nurhayati, F. (2024). Physiological Response to Speed Endurance Soccer Training in Amateur Players. *Physical Education Theory and Methodology, 24*(5), 704-710. https://doi.org/10.17309/tmfv.2024.5.04

Received: 26.07.2024. Accepted: 09.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fizičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Mutual Learning Transfer Between Wrestling and Sumo as Similar Combat Sports Activities: Impact on Youth's Technical Performance and Intrinsic Motivation

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Accepted for Publication: September 9, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.05

Abstract

Objectives. This study aimed to compare the effects of wrestling and sumo wrestling as similar combat sports activities in a training program on technical wrestling scores, wrestling performance indexes, and intrinsic motivation in youth practitioners.

Materials and methods. A randomized controlled trial using a single-blinded design, and repeated measures of parallel groups (sumo-based group: EG, n = 19, aged = 12.42 ± 0.87 years; and only wrestling group: CG, n = 19, aged = 12.41 ± 0.78 years) was conducted. Three 65-minute weekly sessions for four weeks were dedicated to the interventions. A two-factor mixed analysis of variance (ANOVA) model with repeated measures was performed to assess the group vs. time impact analysis.

Results. The findings revealed a significant interaction between the variables, whereby higher values were observed for technical wrestling scores on the attempted head and arm throw test ($F_{1;18}$ = 356.2; $p < 0.001$; ES = 0.60), wrestling performance indexes on the pushing opponent test ($F_{1;18}$ = 8.31; $p = 0.009$; ES = 0.08), intrinsic motivation for effort/importance item ($F_{1;18}$ = 12.24; $p = 0.003$; ES = 0.82) and intrinsic motivation item ($F_{1;18}$ = 19.36; $p = 0.000$; ES = 0.24) in favor of EG.

Conclusions. In conclusion, the sumo-based training program produces significantly greater responses on technical performance, and intrinsic motivation, specifically regarding wrestling training.

Keywords: motivation, combat sports, transfer learning, martial arts, technical performance.

Introduction

Learning should be a pleasure (Mak & Fancourt, 2020), discovering new concepts to understand the world better. Pleasure may seem incompatible with school-based learning and a waste of time for some people (Nailer et al., 2023). According to Ryan and Deci (2021), motivation is a dynamic state relative to each student. For this reason, Wijnia (2020) showed that motivation should be generated in learning so that each student wants to learn. Motivation has been identified as a critical factor influencing student learning outcomes (Lo et al., 2022). Creating an environment conducive to learning seems necessary so that students feel comfortable in it and thus reduce their fear of academic

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achievement (Quansah et al., 2022). From this perspective, Ramlan et al. (2023) stated that transfer involves using previous performance and learning experiences in a particular context and then adapting these experiences to similar or different contexts. The area of affective learning, which aims to promote feelings, attitudes, emotions, and social behavior, has been an educational objective of physical education for almost a century (Testers et al., 2020).

In this sense, a systematic review by Teraoka et al. (2020) shows that physical education classes promote affective learning based on feelings, attitudes, emotions, and social behaviors. Including combat sports in physical education classes stimulates affective learning and the development of motor skills (Pereira et al., 2022). The different modalities of combat sports through continuous, intermittent and object-mediated physical contact are capable of developing multiple motor skills, allowing balanced motor development in children and adolescents (Pereira et al., 2022).

Within combat sports, we find wrestling, which can stimulate discipline in children and youth (Biletic et al., 2023). In this perspective, Melki et al. (2019) have pointed out that wrestling can be fun and safe for children and adolescents. Besides, it allows children to develop physical skills such as speed, agility, and muscular endurance (Genç, 2020), carrying out activities such as pulling, pushing, bending, squeezing, and twisting (Balushka et al., 2020). The critical factor of success in wrestling is technical rather than strength, given that a certain level of strength has been developed to achieve mastery of the technique (Cieśliński et al., 2021). There are two styles of wrestling in competitions, i.e., the Freestyle and the Greco-Roman (Cieśliński et al., 2021). The Freestyle includes the upper and lower body and is characterized by intermittent short-duration and high-intensity efforts (Chaabene et al., 2017). On the other hand, the Greco-Roman style only permitted upper body movements and presented a combat time of 6 min (2 rounds x 3 min) (Chaabene et al., 2017). Besides that, Chaabene et al. (2017) state that wrestling offers various moral development experiences, such as mature self-concept, decision-making, self-control, and sportsmanship. More specifically, for Destani et al. (2014) to use the concept of fair play, students can learn to obey rules and develop personal and social responsibility for their behavior.

Conversely, sumo is a traditional Japanese sport in which two wrestlers fight to push their opponent out of the circle or make any part of their body touch the ground (Nakagawa & Nakagawa, 2022). In this regard, Reicher (2020) indicated the similarity between wrestling and sumo in terms of their technical and physical characteristics. Therefore, sumo wrestlers must develop power, agility, balance, and aerobic capacity (Nakagawa & Nakagawa, 2022). In a study conducted by Beekley et al. (2006) on trained adult sumo wrestlers, they observed that they had higher body weight, body fat percentage, skeletal muscle mass, and maximum oxygen consumption (VO_2max) absolute compared to untrained wrestlers; these differences being significant ($p < 0.05$). However, this may be different according to the age range of the wrestlers, which is indicated by Arakawa et al. (2020) in Japanese elite wrestlers, showing that wrestlers younger than 12 years old show a significant decrease ($p < 0.05$) in body fat percentage compared to wrestlers older than 20 years old.

There is evidence of the effects of wrestling, such as sumo, on anthropometric variables, such as developing technical and tactical skills and affective learning (Beekley et al., 2006; Destani et al., 2014; Melki et al., 2019). So far, the effects on intrinsic motivation, as well as technical and tactical skill development, are unknown when comparing wrestling with sumo as an intervention.

The purpose of the study is to compare the effects of wrestling and sumo wrestling as similar combat sports activities in a training program on technical wrestling scores, wrestling performance indexes, and intrinsic motivation in youth.

Materials and Methods

Participants

According to a previous study in combat sports (Brasil et al., 2020), the ideal number of participants per group was 17 subjects. For this calculation, an average difference of 1.2 % in body fat percentage was used as the minimum difference required for substantial clinical relevance, with a standard deviation of 0.22, considering an alpha level of 0.05 was considered with a power of 80 % and an expected loss of 15 %. GPower software (version 3.1.9.6, Franz Faul, University of Kiel, Germany) was used to calculate statistical power.

The inclusion criteria were: (i) enrolled in a wrestling promotion center in Manouba (It is located in the north of Tunisia, near the coast of the Gulf of Tunis [Mediterranean Sea], the capital of the country, the city of Tunis, and the Mejerda River), that agrees to participate in the intervention; (ii) age range between 10 and 12 years old; (iii) have been practicing for more than 6 months; (iv) attend ≥ 85 % of the sessions scheduled for the training session. Exclusion criteria were the following: (i) any musculoskeletal injuries or medical contraindications (i.e., congenital heart disease, fever, diarrhea, or general malaise) that would prevent their average performance in the assessments and intervention; and (ii) novice practitioners without any prior knowledge of combat sports. This requirement was applied to prevent post-transfer effects between sports (Smeeton et al., 2004). Eligibility was verified for 50 youth: 5 refused participation, 4 were ineligible, and 3 were excluded. A total of 38 participants (22 boys and 16 girls) were randomly assigned to either the EG (n = 19; mean age = 12.42 ± 0.87 years old) or the CG (n = 19; mean age = 12.41 ± 0.78 years old). The youth did not present pain before the assessments or during the training sessions, without presenting injuries during the intervention.

All participants had to accept the criteria for using and handling the data by signing an informed consent and assent form their parents or guardians because they were minors, authorizing the use of the information for scientific purposes. The research protocol was approved by the research of of Universidad Autónoma de Chile (approval number: N° 18-2018) and developed following the Declaration of Helsinki with human beings.

Procedure

We conducted a randomized controlled trial, single-blinded (evaluators), repeated measures of parallel groups with equal distribution of youth in a wrestling promotion

center in Manouba, Tunisia, distributed in experimental group (EG; participated in a training program center on sumo-based as a preparatory phase combined with technical training in wrestling) and a control group (CG; followed only a wrestling technical training). The randomization was performed using the randomizer internet site[1]. The methodology followed was the Consolidated Standards of Reporting Trials (CONSORT) guidelines (Turner et al., 2012). The interventions were conducted over four weeks, comprising 12 sessions. These sessions occurred thrice weekly (on Mondays, Wednesdays, and Fridays) for 65 minutes each. The assessments included anthropometric variables, technical wrestling scores, performance indexes, and intrinsic motivation. All assessments were conducted in the afternoon (between 17:00 and 19:00 h) and in the exact location (wrestling promotion center, with the control of variables, temperature, and investigators that applied the procedures in pre- and post-assessments).

Following the International Society for the Advancement of Kinanthropometry (ISAK), all assessments were performed according to the ISAK guidelines (Marfell-Jones et al., 2012). A digital scale (Seca 769, Germany; accuracy of 0.1 kg) was used to measure body weight, and a stadiometer (Seca 220, Germany; accuracy of 0.1 cm) was used to measure height. Each participant's body mass index (BMI) was calculated by dividing weight in kilograms by the square of height in meters.

An individual assessment grid has been specially designed to assess wrestlers' technical skill during the bouts, covering the following elements (Melki & Bouzid, 2023): (i) number of successful holds by head and arm throws, which is defined by Stordopoulos et al. (2016), as any hold awarding 4 points to a wrestler in a standing position that causes his opponent to lose all contact with the ground, moving him in the air and bringing him to the ground in a position of direct danger, (ii) number of unsuccessful head and arm throws, when the wrestler does not complete the execution of the hold and the referee does not award points and, (iii) number of attempted head and arm throws.

During bouts conducted for both groups at the end of training sessions, a total score of "1" or "4" was awarded to each student who met the two technical performance criteria (United World Wrestling, 2017): (i) pushing the opponent outside the playing area by lifting and controlling him. The referee stops the bout and awards 1 point and, (ii) performing a throw using the head and arm to place the opponent on his back by losing any contact with the mat.

Youth's intrinsic motivation was calculated using an adapted version of Ryan (1982) Intrinsic Motivation Inventory (IMI, in Supplementary Material), the IMI was conducted with students who can speak and understand English (the evaluators tried to explain the inventory both collectively and individually). It comprises fourteen items suitably reworded for the specific context for use in sports settings by McAuley et al. (1989). The IMI contains four subscales: interest/enjoyment, effort/importance, perceived competence, and tension/ pressure. Sample items were: "I enjoyed wrestling very much," "I think I am pretty good at wrestling training," "I put much effort into wrestling training," and "I felt tense while doing wrestling." Students rated their answers on a 7-point scale (1 strongly disagree and 7 strongly agree). These subscales have been used in previous physical education-based studies in which adequate validity and acceptable internal reliability (between 0.68 and 0.84) were demonstrated (McAuley et al., 1989; Wang et al., 2017).

[1] https://www.randomizer.org

Training program

The training program is based on a previous study (Melki & Bouzid, 2023) regarding wrestling techniques and sumo exercises. For both groups (EG and CG), a single session of both programs lasted up to 65 minutes: 10 min of standardized general warm-up, 10 min of specific warm-up based on oppositional skills, followed by 35 min of basic training, followed by individual reference bouts (this bout takes place with a change of time with an objective determined in advance by the coach, for example, only the head and arm throw technique is applied for the duration of the bout) and concluded by a 5-min of wrestling bouts and 5-min recovery period using dynamic and static flexibility exercises. One session was devoted at the end of the training program to assess each participant's morphological variables, technical wrestling scores, wrestling performance indexes, and intrinsic motivation. Both group's (EG and CG) training programs were based on technical wrestling sessions, including learning head and arm throws. For the EG, sumo was used as an associated preparatory phase to the same technical wrestling program. At the end of each training session, all participants participated in one-on-one reference bouts.

The central part of the training program for the EG (sumo-based) consisted of exercises centered on sumo as a preparatory phase combined with technical training for wrestling. The exercises were divided into 15 minutes of sumo varieties: taking the opponent out of a circle, marking the wrestling area, or knocking him down, and 20 minutes of wrestling techniques.

For the CG, the central part consists of 35 min of technical training in wrestling. Lessons included learning the arm and head throwing technique, followed by a series of progressive and complex learning situations. The throwing techniques taught during the 12 lessons were similar to the combined approach: the attacking body positions, arms control, and head position. The complexity of the exercises increased progressively throughout the sessions. At the end of each training session, the participant played wrestling matches freely for 5 minutes. After the intervention program, all participants assessed morphological variables, technical wrestling scores, wrestling performance indexes, and intrinsic motivation.

Statistical Analysis

Firstly, the Shapiro-Wilk test was used to determine the data normality. The values were reported as mean and standard deviation after the normality confirmation ($p > 0.05$). The t-test for independent samples was used to assess differences in youth anthropometric variables, technical wrestling scores, wrestling performance indexes, and intrinsic motivation between the whole sample of the EG and CG. A two-factor repeated measures of analysis of variance (ANOVA) were used to measure the group vs. time

effect of all variables. When the group vs. time interaction was significant, the Bonferroni post-hoc test was applied to establish possible intragroup differences (pre vs. post), while intergroup differences (EG vs. CG) were determined with the Mann-Whitney U test. The effect size (ES) was determined through Cohen's d, considering a small (0.20-0.49), moderate (0.50-0.79), or large (> 0.80) effect (Cohen, 1992). A significant difference was established for all analyses at 5 %. Data were analyzed with SPSS 25.0 statistical software (SPSS 25.0 for Windows, SPSS Inc., Chicago, IL, USA).

Results

The mean differences in anthropometric variables between the EG and CG are presented in Table 1. Indeed, the mixed ANOVA revealed no significant group vs. time interactions for anthropometric variables.

For the Technical Wrestling Score, the group vs. time repeated measures ANOVA with Bonferroni post-hoc test revealed a significant interaction for attempted head and arm throw ($F_{1;18}$ = 356.2; p < 0.001; ES = 0.60. Figure 3, Panel A) in favor of the EG, but without significant interaction for unsuccessful head and arm throw ($F_{1;18}$ = 2.67; p = 0.120; ES = -0.23. Figure 3, Panel B), and successful head and arm throw ($F_{1;18}$ = 0.88; p = 0.360; ES = 0.41. Figure 1, Panel C).

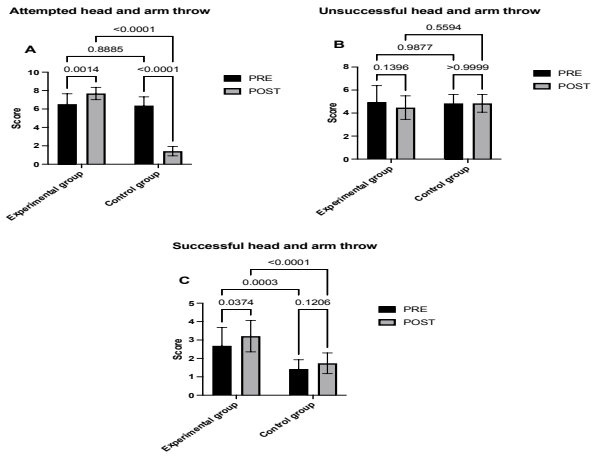

Fig. 1. Intra and intergroup multiple comparisons on technical wrestling score in youth

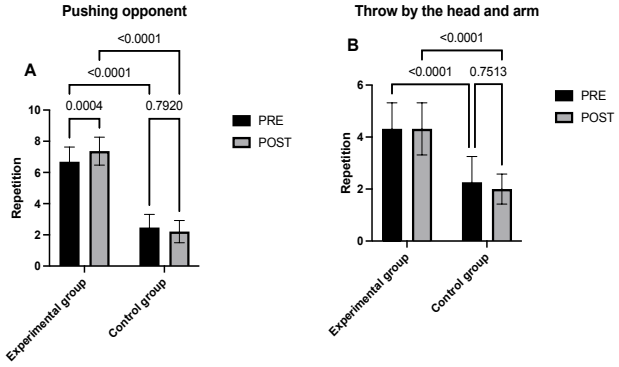

Fig. 2. Intra and intergroup multiple comparisons on wrestling performance index in youth

For the wrestling performance index, the group vs. time repeated measures ANOVA with Bonferroni post-hoc test revealed a significant interaction for pushing opponent ($F_{1;18}$ = 8.31; p = 0.009; ES = 0.08. Figure 4, Panel A) in favor of the EG, but without significant interaction for throw by the head and arm ($F_{1;18}$ = 1.00; p = 0.331; ES = -0.09. Figure 2, Panel B).

Concerning the intrinsic motivation, the group vs. time repeated measures ANOVA with Bonferroni post-hoc test revealed a significant interaction for effort/importance ($F_{1;18}$ = 12.24; p = 0.003; ES = 0.82. Figure 5, Panel C) and intrinsic motivation ($F_{1;18}$ = 19.36; p = 0.000; ES = 0.24. Figure 5, Panel D) in favor of the EG, but without significant interaction for interest/enjoyment ($F_{1;18}$ = 0.10; p = 0.761; ES = 0.21. Figure 2, Panel A), and perceived competence ($F_{1;18}$ = 1.70; p = 0.209; ES = 0.03. Figure 3, Panel B).

Discussion

This study aimed to compare the effects of wrestling and sumo wrestling as similar combat sports activities in a training program on technical wrestling scores, wrestling performance indexes, and intrinsic motivation in youth. The training program lasted four weeks and was based

Table 1. Baseline Characteristics of the sample

Assessment	Group	(Mean ± SD)	p-value	95% CI	η^2
Age (years)	EG (n = 19)	12.42 ± 0.87	0.957	0.59 to 0.56	8.05
	CG (n = 19)	12.41 ± 0.78			
Height (cm)	EG (n = 19)	148.50 ± 3.01	<0.001	2.74 to 7.47	0.35
	CG (n = 19)	153.60 ± 4.10			
Body weight (kg)	EG (n = 19)	48.89 ± 2.98	<0.001	-5.11 to -2.04	0.38
	CG (n = 19)	45.32 ± 1.42			
BMI (kg/m^2)	EG (n = 19)	22.17 ± 1.24	<0.001	-3.74 to -2.12	0.60
	CG (n = 19)	19.24 ± 1.22			

SD: Standard deviation. CI: confidence interval. BMI: body mass index. EG: experimental group. CG: control group. p-value: significant value

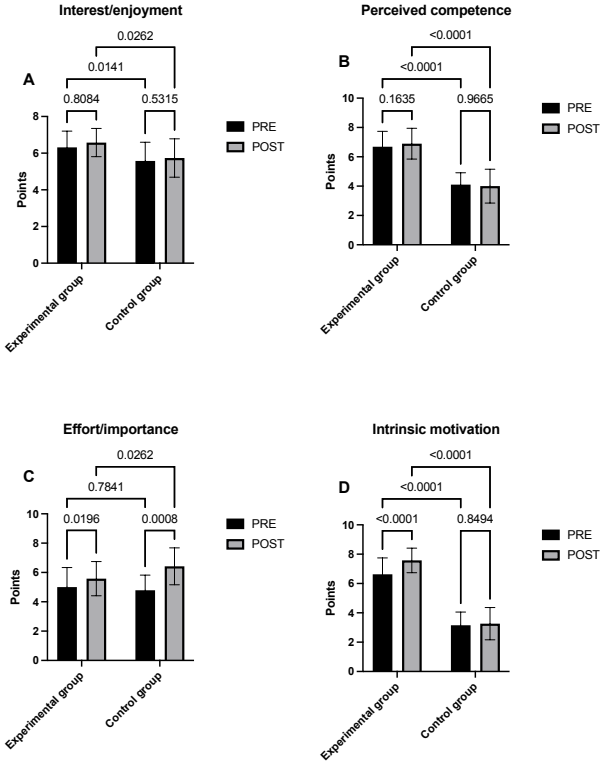

Fig. 3. Intra and intergroup multiple comparisons on intrinsic motivation in youth

on three 65-minute weekly sessions, as stipulated in the wrestling centers' schedule. The primary outcomes indicated the following: (i) for the indices of technical wrestling performance, it was observed that the EG that used the sumo method had a better performance in the test of head and arm throwing attempts with a significant interaction compared to the CG; (ii) the EG had a better wrestling performance index as a result of improvements in the pushing the opponent test, with a significant interaction compared to the CG. Although the throwing and displacement techniques taught during the 12 sessions were similar in both groups, the improvements in the EG that used the sumo method may be due to a positive transfer of motor skills (Soderstrom & Bjork, 2015). The comparison between the technical performances of the two intervention groups showed that the motor learning skills practiced by the participants in this study were more valuable than traditional play and wrestling. In that sense, we must understand motor learning as a set of internal processes associated with practice and experience, which are capable of generating changes in the ability to produce motor activities through a specific skill (Cano-de-la-Cuerda et al., 2015; Torres-Moreno et al., 2022), favoring synaptic neuronal connections, having multiple benefits, such as the coordinated work of the cerebral hemispheres based on their differences and functional specialties (Robinson et al., 2017). Specifically, learning can produce a change in the physical and biochemical structure of the brain, resulting in a brain reorganization that impacts the expression of skills and behaviors (Drews et al., 2013; Tompsett et al., 2017). Furthermore, these adaptations can be expressed globally in forming new synapses or modifying already established synaptic connections (Cano-de-la-Cuerda et al., 2015; Torres-Moreno et al., 2022). In addition, according to Cole et al. (2018), motor learning would not only be generated in the short term, as could be identified in this four-week intervention, but through brain stimulation, it would be shown as an enhancer with long-term retained effects in the primary motor cortex, essential structure to develop motor learning.

Based on the above, our results agree with the specific literature, which supports the positive effects of training programs of different durations on technical performance (Wulf & Lewthwaite, 2016). In contrast, the sumo training sessions influenced the average scores of the EG and showed a higher level of intrinsic motivation than those of the CG, specifically for the effort/importance and intrinsic motivation item. With everything mentioned up to this point, our findings also agree with Parlebas and Dugas (2005), who reported an interspecific learning transfer between similar activities. Also, sumo has been described as a preparatory activity for other sports (Beekley et al., 2006; Nakagawa & Nakagawa, 2022). Our results coincide in regrouping similar activities in the same family. In this sense, Bengué (2000) states that this physical taxonomy confirmed that these activities, whether sports or not, have common characteristics that allow them to be grouped. This positive effect of the sumo approach (i.e., EG) on children's motivation could be because playing is more enjoyable than practicing the technique (Vansteenkiste et al., 2010). Indeed, we noticed that the CG quickly lost their motivation to practice the technique with exercises; in this sense, it is essential to know that the maturation of certain functions accompanies the capacity for sustained and self-directed attention, so it is necessary to seek synchronization of the vestibular, perceptual and visual processes of each child, regardless of their abilities to execute of a program with motor interventions (Emami Kashfi et al., 2019; Torres-Moreno et al., 2022). Our results agree with White et al. (2021), who noted that this finding could be considered a central element in the extent to which physical education teachers should promote an active physical life and showed that sumo-based training could improve children's intentions to become physically active. Apparently, the sumo-based method can be a source of positive transfer, supports intrinsic motivation, and can develop positive attitudes in children and adolescents (González et al., 2018).

Instead, it has been reported that learning training styles affect skill acquisition and transfer, which has posed a significant problem for coaches and trainers seeking to develop the most effective teaching skills (Práxedes et al., 2022). For motor control learning to be effective, Renshaw et al. (2022) confirmed that skill practice must be adaptable to new situations the learner encounters (task-to-task transfer) and that the skill must also be retained over time once acquired. In this sense, wrestling and sumo seem to be physical activity strategies that can be adapted to the needs of children and contribute to their development, which requires further research.

This study's potential limitations include a lack of control over food intake and a failure to complete a food record (to understand the youth's dietary profiles, including their protein, carbohydrate, lipid, and micronutrient intake), both of which could affect the children' technical wrestling scores and wrestling performance indexes. The training program

was four weeks and included only twelve training sessions; thus, our findings should be interpreted cautiously, given that long-term interventions are required to verify them. Finally, only one psychological result has been evaluated: intrinsic motivation. Among the study's main strengths, we could mention the inclusion of an active control group and the randomization of the participants, which improves the internal consistency of the study and increases external validity through protocolized and validated evaluations and a scientifically based training design. We suggest conducting future studies in larger groups that explore other forms of mental power in gaming contexts.

Conclusions

As a preparation activity for wrestling, the sumo-based training program produces significantly greater responses on technical wrestling scores, wrestling performance indexes, and intrinsic motivation regarding only wrestling training in youth. Likewise, the EG (sumo-based) offered significant changes in technical wrestling scores related to the number of attempted head and arm throws and repetitions that pushed the opponent out of the combat area. In addition, it was associated with higher levels of intrinsic motivation and the need to be physically active. The presence of an inter-sport learning transfer related to technical skills in wrestlers' performances should encourage coaches and trainers to develop and optimize training programs that consider technical and physical similarities between certain sports, such as combat sports.

Acknowledgement

The author Hassan Melki would like to express his gratitude to the researchers; MSB and YR who helped to realize all parts of this research.

Conflict of Interest

All authors confirm that there is no conflict of interest in this study.

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Взаємообмін методикою навчання у спортивній боротьбі та сумо як споріднених видів єдиноборств: Вплив на технічну результативність та внутрішню мотивацію юних спортсменів

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 1 табл., 3 рис., 41 джерел.

Мета дослідження. Метою цього дослідження було здійснити порівняльний аналіз впливу спортивної боротьби та боротьби сумо як споріднених видів єдиноборств в рамках тренувальної програми на результати виконання технічних дій у боротьбі, показники результативності боротьби та внутрішню мотивацію молоді, яка займається зазначеними видами спорту.

Матеріали та методи. Проведено рандомізоване контрольоване дослідження із застосуванням одинарного сліпого методу та повторних вимірювань у паралельних групах (група, що займається сумо: ЕГ, n = 19, вік = 12,42 ± 0,87 років; і група, що займається виключно боротьбою: КГ, n = 19, вік = 12,41 ± 0,78 років). Для проведення інтервенцій було передбачено три 65-хвилинних щотижневих сесії протягом чотирьох тижнів. З метою оцінки групового та часового ефекту було проведено двофакторний змішаний дисперсійний аналіз (ANOVA) з повторними вимірюваннями.

Результати. За отриманими даними встановлено значущий взаємозв'язок між змінними, відповідно до якого вищі значення спостерігалися у результатах технічних дій у боротьбі під час тестових випробувань на виконання кидків через голову та за допомогою рук ($F_{1;18}$ = 356,2; p = < 0,001; ES = 0,60), показників результативності боротьби за тестом на відштовхування супротивника ($F_{1;18}$ = 8,31; p = 0,009; ES = 0,08), внутрішньої мотивації за параметром «зусилля/значущість» ($F_{1;18}$ = 12,24; p = 0,003; ES = 0,82) та показником внутрішньої мотивації ($F_{1;18}$ = 19,36; p = 0,000; ES = 0,24) на користь ЕГ.

Висновки. Отже, впровадження тренувальної програми на основі сумо, забезпечує значно вищі показники технічної результативності та внутрішньої мотивації, зокрема, щодо тренувань з боротьби.

Ключові слова: мотивація, єдиноборства, передавальне навчання, бойові мистецтва, технічна результативність.

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Cite this article as: Melki, H., Hernandez-Martinez, J., Herrera-Valenzuela, T., Cid-Calfucura, I., Magnani Branco, B. H., & Valdés-Badilla, P. (2024). Mutual Learning Transfer Between Wrestling and Sumo as Similar Combat Sports Activities: Impact on Youth's Technical Performance and Intrinsic Motivation. *Physical Education Theory and Methodology, 24*(5), 711-719. https://doi.org/10.17309/tmfv.2024.5.05

Received: 25.07.2024. Accepted: 09.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Development and Validation of a Physical Activity-Based Freedom of Movement in Kindergarten

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Accepted for Publication: September 9, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.06

Abstract

Objectives. This study aimed to develop and validate a learning model of physical activity-based freedom of movement in kindergarten.

Materials and methods. This study used a design-based research (DBR) method, which involved twelve experts in early childhood education and physical activity education to help validate the learning model. The stages of development included research and information collecting, planning, development of a preliminary product form, and validation. A statistical analysis was carried out using Aiken's V value to test the model's validity.

Results. This study successfully developed a learning model of physical activity-based freedom of movement in kindergarten, consisting of four main elements: "I love the Earth", "I love Indonesia", "Playing and cooperating" / "We are all siblings", and "My imagination" / "Imagination and creativity". Based on the validity test conducted with twelve experts, the learning model of physical activity-based freedom of movement in kindergarten received an Aiken's V value of 0.82, which exceeds the minimum standard of 0.80.

Conclusions. The findings indicate that implementing the learning model of physical activity-based freedom of movement has been considered as an appropriate pedagogical approach for kindergarten learning. The analysis shows that the model is aligned with children's developmental needs and supports an interactive and creative learning approach consistent with the Merdeka Curriculum in Indonesia.

Keywords: development, validation, physical activity, freedom, kindergarten.

Introduction

The early years of a child's life are crucial for setting the foundation for lifelong health and well-being (Davis et al., 2017). Research suggests that the development of basic movement skills and the implementation of a structured physical activity program in kindergarten are essential (Abusleme-Allimant et al., 2023; Wang et al., 2022; Dapp et al., 2021). These initiatives not only support the physical development of young children but also contribute to their social, emotional, and cognitive growth (Kuzik et al., 2020a). Evidence indicates that engaging in diverse physical activities helps cultivate fundamental movement skills, key to children's overall development and their ability to participate in various physical and recreational activities. Physical activity in early childhood education has fostered holistic development (Aubert et al., 2018). These initiatives crucially promote physical competencies and encourage positive attitudes towards active lifestyles (Messing et al., 2019). Studies emphasize the importance of outdoor play in improving fundamental movement skills, highlighting the direct impact of physical activity on a child's health and development.

Despite the recognized importance of early physical development, a substantial gap exists in offering structured, high-quality physical activity programs in kindergartens (Cheung, 2020). This shortfall is significant because play is crucial for teaching children new social skills, rules, and movements, foundational for their overall growth and development (Giske et al., 2018; Wenz-Gross et al., 2018).

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The Covid-19 pandemic has exacerbated this situation, leading to reduced opportunities for children to engage in fundamental motor skills activities, further widening the gap in physical development support during critical early years (Abe et al., 2022; Moore et al., 2021; Pascal & Bertram, 2021). Regular physical activities are pivotal for improving cardiovascular fitness, enhancing motor skills, and fostering overall health. Research has demonstrated that the goal of play is effective goal play is effective in improving motor skills in early childhood, underlining the importance of such activities in the developmental phase to adapt to others and the environment (Tandon et al., 2020; Han, A. et al., 2018). These structured programs must improve children's ability to develop fundamental movement and motor skills effectively, essential for their physical, cognitive, and social development.

The link between regular physical activity and the cognitive as well as social development of children is well established (Zhao & Chen, 2018). Research has consistently shown that physical activity positively impacts mental function, offering a foundational base for improving academic performance and cognitive development in children (Jylänki et al., 2022; Biddle et al., 2019; Singh et al., 2019). In the context of early childhood education, especially within the innovative framework of the Independent Curriculum in Indonesia, movement-based learning emerges as a potent tool for fostering an environment conducive to creativity and improved learning outcomes (Simarmata & Mayuni, 2023; Mukminin et al., 2019). This curriculum's emphasis on freedom and flexibility in learning strategies aligns with the findings that physical engagement not only bolsters fundamental motor skills but also aids in the holistic development of children, encouraging active participation and engagement in the learning process. The absence of adequate physical activity has been linked to diminished academic performance and cognitive development, underscoring the necessity for structured physical activity programs integrated into the educational curriculum to support children's overall development (de Greeff et al., 2018). This backdrop creates a compelling argument for developing and validating the model of physical activity-based freedom of movement in kindergartens aimed at harnessing the benefits of physical activity for cognitive and social development in a structured and meaningful way.

Educators and institutions face multifaceted challenges in implementing effective physical activity programs (Blewitt et al., 2020). This model of physical activity-based freedom of movement must be suitable for kindergarten learning and promote cognitive, affective, and psychomotor development in young learners. Designing a learning model that balances the educational objectives with the physical development needs of children requires a nuanced understanding of how physical activity influences learning and development across different domains (DiPietro et al., 2020). Evaluating these models' effectiveness poses challenges, including identifying appropriate metrics and assessment tools that accurately measure outcomes in cognitive, affective, and psychomotor domains (Han, J. et al., 2023; Gilic et al., 2022). Integration into existing curricula is another significant hurdle, as it necessitates reevaluating traditional teaching methods and incorporating physical activities to complement and enhance the educational experience without disrupting the learning flow (Mavilidi et al., 2018). These challenges underscore the need for comprehensive model design criteria that consider the diverse benefits of physical activity and strategies for overcoming obstacles related to unclear aims, inappropriate delivery methods, and the harmonious blending of physical activities into educational frameworks.

Materials and Methods

Study Participants

The study's participants comprised a carefully selected group of experts and practitioners in early childhood education and physical activity for young children. Specifically, the expert group consisted of twelve individuals renowned in their respective domains: one academic expert in early childhood education and one in physical activity from Higher Education Institutions, alongside four seasoned early childhood education experts who serve as senior kindergarten principals in Yogyakarta. This diverse assembly of experts was chosen based on their extensive experience, scholarly contributions, and practical insights into developing and implementing physical activity in early childhood settings. This study also involved six expert practitioners and senior early childhood educators from various kindergartens in Yogyakarta. These expert practitioners were selected due to their direct involvement and firsthand experience in facilitating young children's learning and physical development within the kindergarten environment.

Study Organisation

The research method in this study is Design-Based Research (DBR). This methodology systematically designs interventions to improve educational practices through a collaborative approach involving educators, researchers, and other stakeholders. Within this framework, the study seeks to address real-world problems in kindergarten by developing and validating a model of physical activity-based freedom of movement. This methodology supports the continuous refinement of educational strategies based on feedback and findings from each implementation phase, allowing for the adaptation and improvement of the model to meet specific needs effectively (Tinoca et al., 2022). Through DBR, this study aims to create a practical, evidence-based program that can enhance young learners' engagement in kindergarten students' physical activity, thereby promoting their overall well-being and laying a solid foundation for a lifelong active lifestyle.

The research procedures in this study are divided into four main stages: research and information collecting, planning, development of the preliminary form of a product, and validation. This structured approach ensures a systematic approach to developing and validating the product (Komaini et al., 2021). The initial stage, research and information collecting, encompasses a comprehensive range of activities, including literature review, observation, documentation, expert interviews, surveys, needs analysis, focus group discussions, and conceptual framework development. This stage is crucial for gathering relevant data and insights that will inform the subsequent phases of the study, ensuring that the

development of the model physical activity is grounded in solid research and meets the identified needs and interests of kindergarten students, as well as the requirements of their teachers and parents.

In the planning stage, the collected data from the research and information collecting phase is analyzed and synthesized to gain a deeper understanding of kindergarten students' specific needs and interests in physical activity, incorporating the concept of freedom of movement. This understanding is critical for designing an effective physical activity that aligns with the developmental stages and interests of the target group. Following the planning phase, the development of the preliminary form of a product phase involves designing, developing, and drafting an initial model of the planned physical activity-based freedom of movement in kindergarten. This preliminary model is crafted carefully considering the insights gained from the earlier stages, aiming to create an engaging, developmentally appropriate, and pedagogically sound program that promotes a model of physical activity-based freedom of movement in kindergartens.

Twelve experts were tasked with the evaluation process in the pedagogical experiment designed to assess the quality model of physical activity-based freedom of movement in kindergartens. These evaluators are selected based on stringent criteria to ensure a comprehensive and informed assessment. First, each expert and practitioner must possess at least five years of experience in their respective fields. This experience is crucial for providing a depth of understanding and insight into the model's effectiveness and applicability. Second, the evaluators must be active practitioners, lecturers, or teachers in early childhood education and physical activity. This ensures they have current and relevant experience with the age group and subject matter. Finally, a deep understanding of key topics is mandatory: early childhood education, physical activity, freedom of movement, and the independent curriculum. This multidimensional expertise is essential for assessing the model's potential to enhance physical education in kindergartens, fostering a holistic approach to developing young children within the framework of the modern educational landscape.

Statistical Analysis

This study's data analysis techniques encompass quantitative and qualitative methodologies to thoroughly evaluate the effectiveness model of physical activity-based freedom of movement in kindergartens. The quantitative aspect of the analysis utilized an evaluation form featuring a five-point Likert rating scale, with scores ranging from 5 (highly appropriate) to 1 (highly inappropriate). This scale facilitated the structured data collection regarding the appropriateness and effectiveness of the model from the perspectives of experts and practitioners. The development of this instrument drew upon the foundational work of ensuring a grounded approach in relevant prior research (Boa et al., 2018). Subsequently, the collected data were analyzed using SPSS version 23, a statistical software package, to calculate the mean, standard deviation, and V Aiken values. These statistical measures provided insights into the validity of the quantitative model, offering a rigorous assessment of the model's efficacy. The choice of SPSS for data analysis underscores the study's commitment to employing robust statistical tools to derive meaningful conclusions from the data collected, thereby ensuring a comprehensive evaluation of the pedagogical intervention (Afifah et al., 2022).

The selection of quantitative and qualitative data analysis techniques comprehensively assessed the suitability model of the physical activity-based freedom of movement for integration into the kindergarten learning process. The quantitative analysis allowed for the numerical evaluation of responses obtained through the Likert rating scale, providing measurable insights into the appropriateness and effectiveness of the model. On the other hand, qualitative analysis provided a deeper understanding of the nuanced perspectives and experiences of experts and practitioners regarding the feasibility and potential impact of the model. Combining these two approaches, the study offered a holistic evaluation that would inform decision-making regarding incorporating the model into kindergarten curricula, ensuring a well-rounded assessment of its pedagogical efficacy and suitability for educational contexts.

Results

The first stage in developing a model of physical activity-based freedom of movement in kindergarten is research and information collection. In this study, the research and information collection stage consists of a literature review, observation, documentation, expert interviews, surveys, needs analysis, focus group discussions, and the formulation of a conceptual framework. This stage is crucial as it provides the foundational groundwork that significantly influences the success model of developing a physical activity-based freedom of movement in kindergarten. The following diagram explains the process of research and information collection in this study:

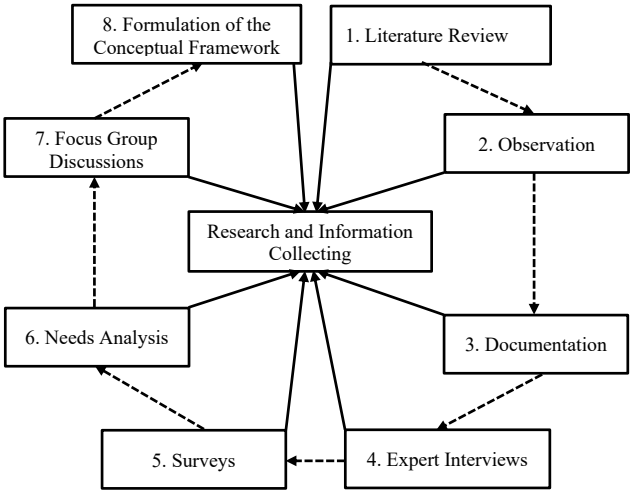

Fig. 1. Research and Information Collection Design

Planning is the next stage to be undertaken after the research and information collection process. During the planning stage, analysis and synthesis of the data collected during the research and information collection process are carried out. The main data in this context pertains to the needs and interests of kindergarten students and the

needs of teachers and parents regarding the learning process of physical activities based on freedom of movement in kindergarten. Based on the analysis and synthesis conducted, a model of physical activity for kindergarten students that is effective and suitable for the needs of the students and their surrounding environment is ultimately designed.

The designed physical activity model will include various activities based on freedom of play, which involves minimal teacher intervention and interpretations of fundamental movements. These basic movements consist of exploration, chasing, fleeing, dodging, volleying, dribbling, spatial awareness, kicking, directing, throwing, catching, dancing proficiency, understanding relationships, striking with a racket, striking with a long-handled implement, game skills, effort, perseverance, weight transfer, rolling, jumping, landing, and gymnastics skills.

In the Develop Preliminary Form of a Product stage, the researcher successfully integrated various concepts and elements obtained during the Planning stage into a cohesive activity model. This initial model includes all the aspects of the designed physical activity model, such as various physical activities, teaching methods and techniques, and implementation guidelines to support the successful application of the developed model. The following is the design of a physical activity-based freedom of movement program in kindergartens that has been created.

The next step after research and information collection and developing a preliminary form of a product is the validation of the model by twelve practitioners, including academic experts, senior kindergarten principals, and senior early childhood education educators. The validation is based on internal and external factors. The internal factors consist of five indicators: model quality, results alignment with objectives, model clarity, model novelty, and data source reliability. The external factors comprise five indicators: model relevance, policy implications, theoretical contribution, model generalization, and model user suitability. The following are the data analysis results of validating a physical activity-based freedom of movement in kindergarten, conducted using SPSS.

In the model validation stage conducted with twelve experts, the data obtained are presented in Table 1. Based on the model validation, it is found that the model of physical activity-based freedom of movement program in kindergartens has a mean of 4.29, a standard deviation of 0.44, and an achievement percentage of 85.83 %. Furthermore, Aiken's V analysis was conducted with five assessment categories to evaluate the feasibility of a model of physical activity-based freedom of movement program in kindergartens. According to the minimum standard for Aiken's V in validity testing, this model shows a value of 0.80 with a probability of 0.05. The Aiken's V test calculation for the validation process data by twelve experts indicates a score of 0.82, which signifies that the model is considered valid for use according to the experts' assessment.

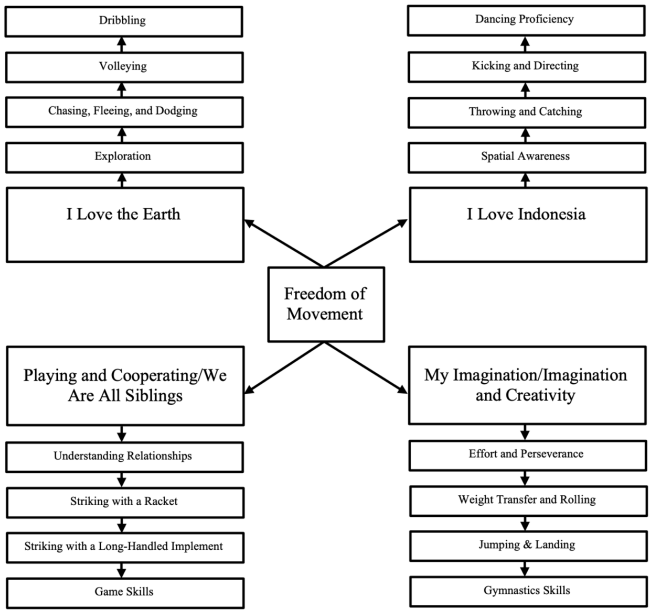

Fig. 2. Design of the Physical Activity-Based Freedom of Movement in Kindergarten

Discussion

This study aims to develop and validate a model of physical activity-based freedom of movement program in kindergartens. Based on the validation and evaluation results by experts and practitioners, this model has proven valid and suitable for application in early childhood education. The validation indicates that the model aligns with the ten established indicators: Alignment with research objectives, alignment of research results, clarity of conclusions, novelty of findings, reliability of data sources, relevance of the research theme, policy implications, contribution to theory, generalization of findings, and quality of findings. These aspects are crucial for the comprehensive development of early childhood education, as supported by studies from Smith et al., (2022) and Wyatt-Smith et al., (2024) which highlight the importance of aligning educational models with clear objectives and reliable data. The model is designed with various important aspects in mind, such as quality, clarity, novelty, and relevance to the educational goals for early childhood in Indonesia.

The results of this study align with various related publications discussed in the introduction. Based on the model validation stage conducted with twelve experts, data indicate that a model of physical activity-based freedom

Table 1. Validation Results of the Physical Activity-Based Freedom of Movement in Kindergarten

	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	E_{11}	E_{12}	Mean
Mean	4.40	3.50	4.25	4.10	4.80	3.50	4.25	4.85	4.75	4.15	4.25	4.70	4.29
Standard Deviaton	0.50	0.51	0.44	0.31	0.41	0.51	0.44	0.37	0.44	0.37	0.44	0.47	0.44
Achievement Percentage	88 %	70 %	85 %	82 %	96 %	70 %	85 %	97 %	95 %	83 %	85 %	94 %	85.83 %
V Aiken Values													0.82

of movement program in kindergartens has an Aiken V value of 0.82, surpassing the minimum standard of 0.80. This suggests that the developed model is considered valid by the experts. These findings support previous research, such as that by Wang et al. (2023) and Abusleme-Allimant et al. (2023) which emphasizes the importance of structured physical activity models in supporting children's physical and cognitive development. This study also reinforces the findings of Jeon & Jun (2021), Kuzik et al. (2020) and Jones et al. (2019) which show that engagement in diverse physical activities can enhance fundamental motor skills and holistic development in children. Consistency with research by Martín-Rodríguez et al. (2024) is also evident, highlighting that physical activity improves physical competence and fosters a positive attitude towards an active lifestyle. Furthermore, this study supports the findings of (Nordmo & Meland, 2023) and (Laxdal et al., 2020) regarding the significance of outdoor play in enhancing fundamental motor skills and children's health.

Considering the potential practical application of this research, it is important to emphasize that a model of physical activity-based freedom of movement program in kindergartens can be easily integrated into the Indonesian kindergarten curriculum. This model is designed with early childhood developmental needs in mind and can be adapted to suit each school's local context and specific needs. Implementing this model requires support from teachers, parents, and policymakers to ensure its success and optimal benefits for children's development. These findings align with previous studies by Kemble et al. (2024) and Belton et al. (2022) highlighting the importance of integrating physical activity into early childhood education to support holistic development. Additionally, the necessity of teacher training and support in implementing such models is supported by research from Barnett et al. (2019) which emphasizes that professional development for educators is crucial in achieving the desired outcomes in children's physical and cognitive growth. This study also resonates with the findings of Cassar et al. (2019) and Ward et al. (2018) underscoring the role of comprehensive school and community support in successfully adopting physical activity programs in early education settings.

The results of this study open opportunities for further research to examine the long-term effectiveness of this model and its impact on a broader population. Future research could explore various evaluation and measurement methods to understand better the model's effects on wider aspects of child development. These considerations are supported by studies such as those by Siraj et al. (2023) and Hofstee et al. (2022) which emphasize the importance of longitudinal research in assessing the sustained impact of early childhood interventions. Additionally, subsequent studies might investigate the factors influencing the successful implementation of this model, including the role of teachers, institutional support, and family participation. Thus, this research provides a solid foundation for practical application and offers clear directions for further research and development in early childhood education.

Conclusions

This study successfully developed and validated a physical activity model based on freedom of movement in kindergarten. It is suitable for kindergarten learning and aimed at enhancing children's physical, cognitive, and social development in their early years of education. Validation by twelve experts revealed that the developed physical activity model has an Aiken V value of 0.82, exceeding the minimum standard of 0.80, thus confirming that the model is valid and suitable for use. The analysis shows that the model aligns with children's developmental needs and supports an interactive and creative learning approach consistent with the Independent Curriculum in Indonesia. In addition to stimulating children's motor skills, the model also significantly contributes to the overall quality of education in kindergarten.

The results of this study are consistent with various previous studies that emphasize the importance of structured physical activity in supporting children's development. This model can be easily integrated into the kindergarten curriculum with support from teachers, parents, and policymakers. Training for teachers is also crucial to ensure the model's effectiveness. This research opens opportunities for further investigation into the model's long-term efficacy and impact on a broader population, as well as exploring factors influencing the successful implementation of the model, including the role of kindergarten teachers and support from Indonesian government institutions.

Acknowledgment

We sincerely thank the authors and institutions for continuously supporting this research. We also extend our appreciation to the academic community of Semarang State University. Furthermore, we are very grateful to the principals and kindergarten teachers in Yogyakarta for their support throughout the research process.

Conflict of interest

All authors confirm that we have no conflicts of interest.

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Розробка та валідація моделі фізичної активності, що базується на забезпеченні вільного рухового режиму в дитячому садку

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 1 табл., 2 рис., 47 джерел.

Мета дослідження. Мета цього дослідження полягала в розробці та валідації навчальної моделі фізичної активності на основі вільного рухового режиму в дитячому садку.

Матеріали та методи. У роботі застосовано методику дизайн-орієнтованого дослідження (англ. design-based research, DBR), до якої було залучено дванадцять експертів у галузях дошкільної освіти та фізичного виховання з метою валідації навчальної моделі. Етапи розробки включали дослідження та збір інформації, планування, розробку попередньої форми продукту та валідацію. Для перевірки валідності моделі було проведено статистичний аналіз з використанням V-значення коефіцієнта Ейкена.

Результати. У рамках цього дослідження було успішно розроблено навчальну модель фізичної активності, що базується на забезпеченні вільного рухового режиму в дитячому садку, яка складається з чотирьох основних елементів: «Я люблю планету Земля», «Я люблю Індонезію», «Граємо і співпрацюємо» / «Ми всі брати і сестри» та «Моя уява» / «Уява і творчість». Відповідно до результатів тесту на валідність, проведеного за участю дванадцяти експертів, навчальна модель фізичної активності на основі вільного рухового режиму в дитячому садку отримала V-значення коефіцієнта Ейкена на рівні 0,82, що перевищує мінімальний стандарт у 0,80.

Висновки. Отримані результати свідчать про те, що застосування навчальної моделі фізичної активності на основі вільного рухового режиму розглядається в якості відповідного педагогічного підходу для навчання в дитячому садку. Аналіз показує, що зазначена модель відповідає потребам розвитку дітей і забезпечує інтерактивний і творчий підхід до навчання згідно з навчальною програмою «Мердека» в Індонезії.

Ключові слова: розвиток, валідація, фізична активність, свобода, дитячий садок.

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Cite this article as: Hidayat, A. K., Setyawati, H., Hidayatullah, F., & Hartono, M. (2024). Development and Validation of a Physical Activity-Based Freedom of Movement in Kindergarten. *Physical Education Theory and Methodology, 24*(5), 720-727. https://doi.org/10.17309/tmfv.2024.5.06

Received: 27.07.2024. Accepted: 09.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Assessing the Effect of Short-Term Interval Training on Acceleration Ability and Anaerobic Power of Novice Sprinters

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Accepted for Publication: September 9, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.07

Abstract

Background. Acceleration ability and anaerobic power are critical determinants of sprinting performance, particularly for novice sprinters.

Objectives. The purpose of the study was to examine the effects of a four-week interval training program on acceleration ability and anaerobic power among novice sprinters.

Materials and methods. A within-subjects quasi-experimental design was used to fulfil the study's objectives. A total of fifteen participants (age: 20.5 ± 1.4 years) underwent baseline assessments of acceleration ability (50 m dash) and anaerobic power (Running-Based Anaerobic Sprint Test). The adopted progressive interval training protocol consisted of four weekly sessions conducted over a four-week period, focusing on striding, high knees, single-leg hops, curve sprints and double-leg jumps to enhance acceleration ability and anaerobic power.

Results. Following the intervention, significant improvements were observed in acceleration ability over a distance of 10 m (pre: 2.14 ± 0.16 s, post: 2.02 ± 0.14 s, $p < 0.05$, Cohen's $d = 1.02$) and 20 m segments (pre: 3.47 ± 0.23 s, post: 3.32 ± 0.20 s, $p < 0.05$, Cohen's $d = 0.78$), indicating moderate to large effect sizes. However, no considerable enhancements were found in anaerobic power parameters (average power, maximum power, minimum power, fatigue index, relative peak power, and anaerobic capacity) at the post-intervention stage ($p > 0.05$).

Conclusions. The study highlights the effectiveness of the interval training protocol in enhancing initial acceleration among novice sprinters, although it suggests a limited impact on anaerobic power within the study period. Further research should investigate the longer-term effects and tailored training approaches to optimize comprehensive sprint performance strategies.

Keywords: acceleration, anaerobic power, RAST, athletes.

Introduction

Acceleration ability and anaerobic power are fundamental components contributing to the success of sprinters, particularly novices, in short-distance races (Duffield et al., 2006). Acceleration, defined as the rapid increase in speed from a stationary position, and anaerobic power, characterized by the ability to exert high-intensity force in a short duration, is critical determinants of sprinting performance (Tabata et al., 1996). These attributes heavily rely on the anaerobic energy system, which encompasses the phosphagen (ATP-PCr) system and anaerobic glycolysis (MacDougall et al., 1998). To optimize these energy pathways, interval training has emerged as a potent method (Gibala et al., 2006). Interval training, marked by alternating periods of intense activity and rest or low activity, is widely recognized for its efficacy in improving athletic performance (Helgerud et al., 2007). It is particularly advantageous for sprinters as it targets both anaerobic and aerobic capacities, crucial for explosive power and sustained high performance (Laursen & Jenkins, 2002). Despite the well-established benefits of interval training, its specific effects on the acceleration ability and anaerobic power of novice sprinters over a short duration, such as four weeks, remain underexplored (Buchheit & Laursen, 2013). Understanding these effects is imperative

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for coaches and athletes to devise training programs that maximize performance improvements within a brief timeframe. Previous research has demonstrated the efficacy of interval training in enhancing anaerobic power across various athlete groups (Tabata et al., 1996). These enhancements are attributed to physiological adaptations such as increased muscle glycogen storage, enhanced lactate clearance, and improved neuromuscular coordination (MacDougall et al., 1998). Furthermore, interval training induces metabolic changes in muscle fibers, leading to improved functionality of the ATP-PCr system and enhanced buffering capacity (Ross & Leveritt, 2001). However, there is a notable research gap regarding the specific effects of interval training on novice sprinters' acceleration ability and anaerobic power within a short timeframe. Hence, this study aims to address this gap by investigating the impact of a four-week interval training program on the acceleration ability and anaerobic power of novice sprinters. By focusing on a specific training regimen, this research seeks to ascertain the effectiveness and rapidity of interval training in enhancing key performance metrics among beginner athletes. The findings of this study will not only contribute to the existing knowledge base on the benefits of interval training but also offer practical insights for coaches and athletes seeking to optimize sprint performance rapidly. By informing training strategies that target the development of essential performance components in novice sprinters, this research aims to enhance the efficacy of athletic training protocols, ultimately leading to improved athletic performance.

Materials and Methods

Participants

A total of 15 novice sprinters (age: 20.5 ± 1.4 years, height: 167.0 ± 5.7 cm, body mass: 58.1 ± 10.1 kg) were randomly selected from local athletic clubs in Panskura, Purba Medinipur. All participants had no prior experience with structured interval training. Individuals with any pre-existing medical conditions affecting physical activity were excluded from the study. Informed consent was obtained from all participants prior to their involvement in the study and they were made aware of the study's purpose, procedures, potential risks and benefits. Confidentiality of participant data was maintained throughout the study and identifying information was removed from all reports and publications. Any adverse events or injuries arising during the study were promptly addressed and reported to the appropriate authorities. The data of four volunteers were excluded due to inconsistency in training. The study design obtained approval from the Institutional Ethical Committee of Panskura Banamali College (Autonomous), West Bengal, India.

Experimental Design

A within-subjects quasi-experimental design has been employed, where each participant will serve as their own control. Participants will undergo baseline assessments

Table 1. Prescribed interval training protocol (4 session/week for 4 weeks) to improve acceleration ability and anaerobic power

Week	Activity/Exercise	D.A	DR	Rep.	Sets (no)	R.R	Remarks
	Stride	20	30	4	2	2	Focus on maintaining form
	High Knee	20	30	4	2	2	Emphasize high knee lift
1	Single Leg Hop	20	30	4	2	2	Ensure proper landing technique
	Curve Sprint	60	80	4	2	2	Start with moderate pace
	Double Leg Jump	20	30	4	2	2	Use explosive power
	Stride	25	35	4	2	1.5	Increase intensity
	High Knee	25	35	4	2	1.5	Maintain high intensity
2	Single Leg Hop	25	35	4	2	1.5	Focus on height and distance
	Curve Sprint	70	90	4	2	1.5	Increase speed gradually
	Double Leg Jump	25	35	4	2	1.5	Enhance explosive power
	Stride	30	40	5	2	1.5	Increase repetitions
	High Knee	30	40	5	2	1.5	Maintain intensity
3	Single Leg Hop	30	40	5	2	1.5	Focus on power and control
	Curve Sprint	80	100	4	2	1.5	Aim for higher speed
	Double Leg Jump	30	40	5	2	1.5	Maximize jump distance
	Stride	35	50	5	2	1	Final intensity push
	High Knee	35	50	5	2	1	Maintain high knees throughout
4	Single Leg Hop	35	50	5	2	1	Enhance hop distance
	Curve Sprint	90	110	4	2	1	Reach maximum speed
	Double Leg Jump	35	50	5	2	1	Maximize explosive power

D.A: Distance of Activity (meter), DR: Distance for Recovery (meter), Rep.: Repetition (numbers), R.R: Rest between Repetition (minutes)

of acceleration ability and anaerobic power prior to the intervention. Following the baseline assessments, participants will engage in a four-week prescribed interval training program designed to target both acceleration ability and anaerobic power. Post-intervention assessments will be conducted immediately after the completion of the four-week training program to evaluate the effects of that interval training.

Prescribed Intervention

A warm-up and cool-down session has been incorporated before and after training to reduce the risk of injuries. To support the increased physical demands of the training program, individuals are advised to consume adequate food and water.

Outcome Measures

Acceleration Ability has been assessed using the 50 m dash test. All participants sprinted over a 50 m distance, which was subdivided into four equal segments of 10 m each. The time duration of each splitting segment and the total 50 m distance covering time were recorded by officials affiliated with the West Bengal Athletic Association (WBAA) using a stopwatch. Anaerobic power has been evaluated by the Running-based Anaerobic Sprint Test (RAST). Participants performed six maximal 35 m sprints with 10-second intervals between each sprint. Time to complete each sprint and the total sprint time were recorded by WBAA affiliated officials using a stopwatch.

Data Analysis

The study employed descriptive and inferential statistics for data analysis, including the Anderson-Darling test to assess the normality of hypotheses. Following the evaluation of data distribution, parametric analysis was conducted. Both acceleration ability and anaerobic power were measured before and after the intervention, with a comparison made using paired sample t-tests, depending on data distribution. Effect sizes were computed to gauge the magnitude of change post-intervention. Data were consistently presented as mean ± standard deviation, with a significance level of $\alpha \leq 0.05$. Analytical procedures and graphical presentations were conducted using Jamovi (ver. 2.5.3) and Gnumeric spreadsheet (ver. 1.12.48), freely available statistical software tools.

Results

The table 2 summarizes the cumulative times novice sprinters took for a 50-meter dash before and after a non-invasive intervention aimed at improving acceleration. The results indicate improvements in all measured segments: 10 m, 20 m, 30 m, 40 m, and 50 m. The average times for each segment were consistently lower than the pre-intervention times indicate a positive impact of training. Furthermore, the standard deviations for most segments either decreased or remained stable, suggesting that the sprinters' performances became more consistent following the intervention. The 95 % confidence intervals for each segment's mean times further confirm the statistical significance of these improvements. Overall, the intervention effectively enhanced the acceleration abilities of the novice sprinters, as evidenced by the reduced times across all segments of the 50-meter dash.

Table 2. Descriptive statistics of cumulative time taken for 50 m dash before and after intervention to measure acceleration ability non-invasively

Distance (m)	Pre-test (time in sec)	Post-test (time in sec)	t	p
10 m	2.34 ± 0.17 (2.22-2.45)	2.20 ± 0.14 (2.10-2.30)	2.065	0.052
20 m	3.79 ± 0.24 (3.62-3.95)	3.53 ± 0.25 (3.36-3.70)	2.39	0.027
30 m	4.93 ± 0.35 (4.70-5.17)	4.73 ± 0.40 (4.46-5.00)	1.285	0.213
40 m	6.17 ± 0.60 (5.76-6.57)	6.08 ± 0.52 (5.73-6.43)	0.357	0.725
50 m	7.69 ± 0.58 (7.30-8.08)	7.40 ± 0.58 (7.01-7.79)	1.184	0.25

Data are presented as mean ± SD (95 % confidence intervals)

Figure 1 illustrates the impact of an intervention on acceleration and speed, comparing pre-test and post-test values at different intervals (0 m, 10 m, 20 m, 30 m, 40 m, and 50 m). Before the intervention, acceleration increases up to 20 m, peaks, and then decreases. Post-intervention, acceleration follows a similar pattern but with generally higher values, showing improvements at 10 m, 20 m, and 50 m, despite decreases at 30 m and 40 m. This indicates that the intervention enhanced sprint performance at certain distances. Speed analysis reveals a consistent increase post-intervention: from 1.9 m/s to 2.09 m/s (0-10 m), 4.9 m/s to 5.8 m/s (10-20 m), 7.7 m/s to 8.3 m/s (20-30 m), 5.8 m/s to 6.7 m/s (30-40 m), and 5.1 m/s to 5.9 m/s (40-50 m). These steady increments in speed suggest that the intervention was effective in improving performance across all measured intervals, with the most significant gains observed between 10-20 m and 20-30 m. The overall data indicates a successful intervention, enhancing speed and acceleration in a consistent and reliable manner.

Figure 2 provides a comparative analysis of the time taken to complete each 10-meter segment of a 50-meter sprint before and after an intervention. Before the intervention, the time taken for each segment generally showed more variability and slightly slower times. After the intervention, there was a noticeable improvement, with faster times observed across almost all segments. The initial segments, particularly the first 20 meters, showed the most significant reductions in time. From this point of view, the intervention effectively enhanced sprint performance, especially in the early phases of the sprint.

Table 3 presents descriptive statistics of various anaerobic power components before and after an intervention, assessed using the Running-Based Anaerobic Sprint Test (RAST). Parameters analyzed include Average Power, Maximum Power, Minimum Power, Fatigue Index, Relative Peak Power, and Anaerobic Capacity. Comparison of pre-test and post-test measurements reveals significant changes in all parameters,

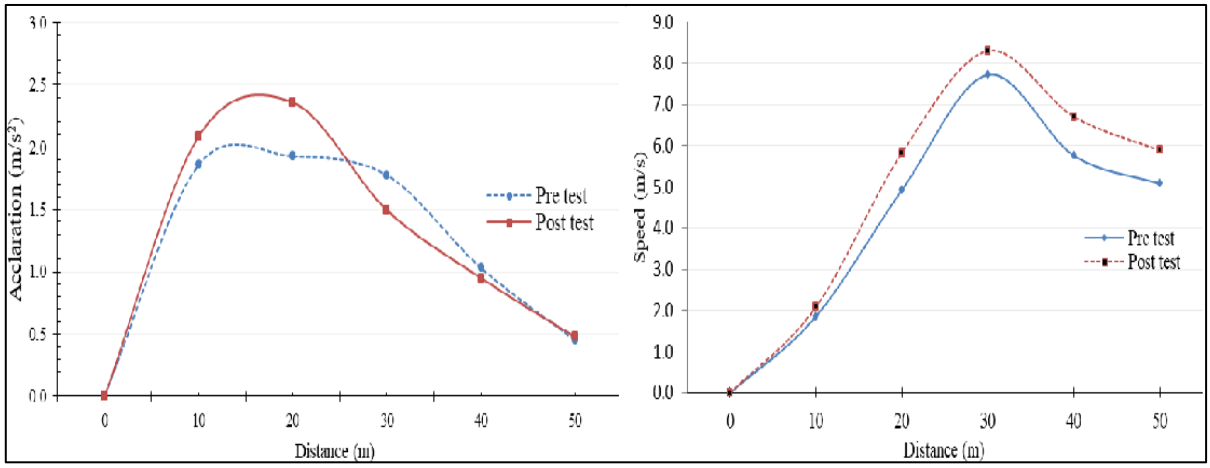

Fig. 1. Graphical comparison of acceleration ability and speed before and after intervention

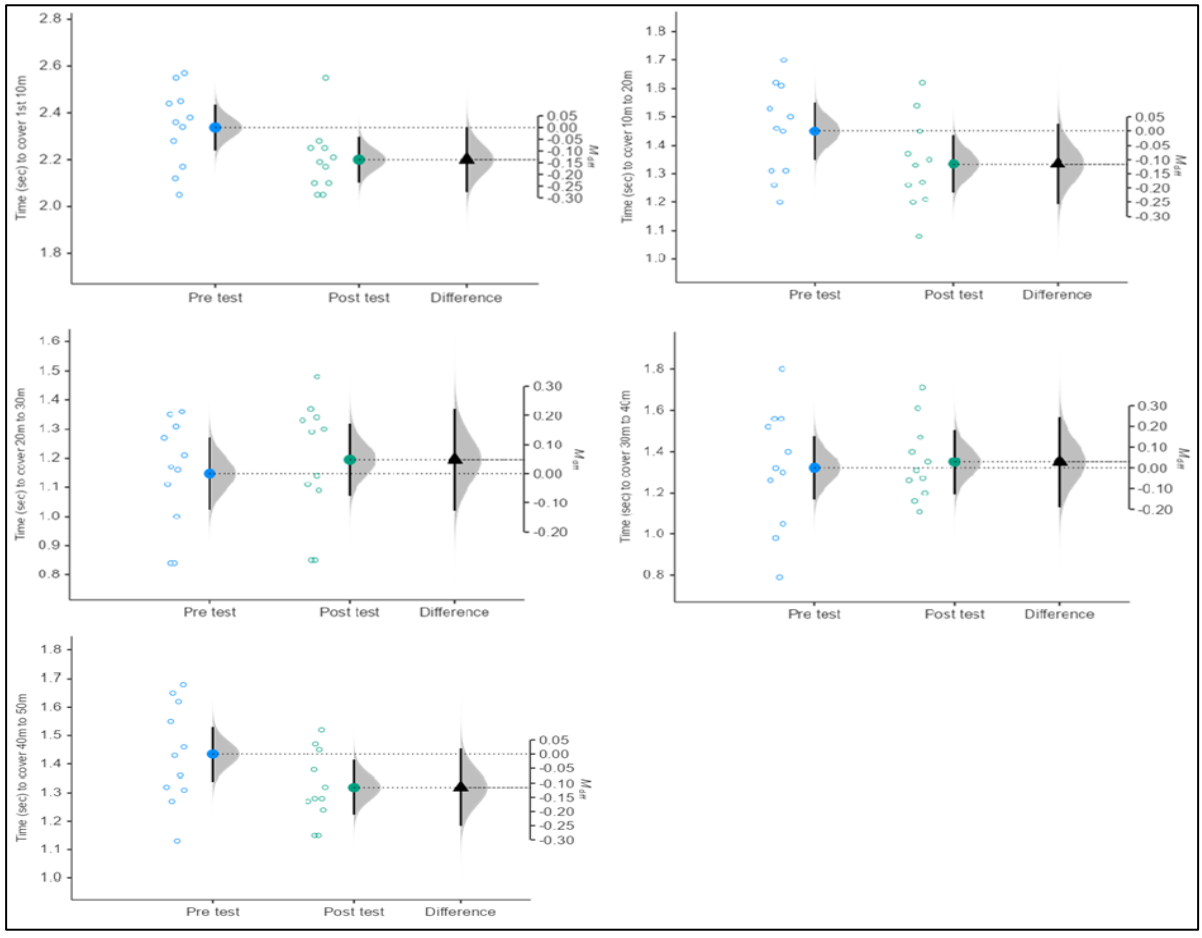

Fig. 2. Graphical representation of segment wise duration of time taken before and after the intervention

with post-intervention values showing higher average, maximum, and minimum power, alongside a reduced Fatigue Index. Moreover, Relative Peak Power and Anaerobic Capacity exhibit notable increases post-intervention. These results suggest that the intervention effectively enhanced anaerobic power components, signifying its efficacy in improving anaerobic performance. The inclusion of mean values, standard deviations, and 95 % confidence intervals ensures the robustness and thoroughness of the analysis, enhancing its suitability for scientific research purposes.

Table 4 presents the effects of prescribed interval training on acceleration ability and anaerobic power, assessed through various parameters. For acceleration ability, significant improvements are observed in the

Table 3. Descriptive statistics of anaerobic power components before and after intervention using the running-based anaerobic sprint test (RAST)

Parameters	Pre test	Post test
Ave. Power (Watt)	292.65 ± 81.3 (238.03 - 347.26)	332.93 ± 78.69 (280.06 - 385.79)
Max. Power (Watt)	379.55 ± 98.39 (313.45 - 445.65)	405.89 ± 88.75 (346.27 - 465.52)
Min. Power (Watt)	213.15 ± 77.94 (160.79 - 265.52)	266.06 ± 76.06 (214.96-317.16)
Fatigue Index (Watt)	4.40 ± 1.86 (3.15 - 5.65)	3.86 ± 1.65 (2.75 - 4.97)
Relative Peak Power (Watt)	5.04 ± 1.12 (4.29 - 5.79)	5.82 ± 1.13 (5.06 - 6.58)
Anaerobic Capacity (Watt)	1755.86 ± 487.76 (1428.18 - 2083.54)	1997.55 ± 472.25 (1680.29 - 2314.82)

Data are presented as mean ± SD (95% confidence intervals)

10-20 m distance, as indicated by the t statistic of 2.39 and a p-value of 0.03. This interval training resulted in a mean difference of 0.25 m/s^2 with a moderate effect size of 1.02. In contrast, other intervals did not show statistically significant changes. Regarding anaerobic power, there were no significant improvements observed in average, maximum, and minimum power, as well as in fatigue index and anaerobic capacity. However, a trend towards improvement is noted in minimum power, with a t statistic of -1.61 and a p-value of 0.12, suggesting a potential effect. The effect sizes across anaerobic power parameters range from small to moderate. These findings suggest that while prescribed interval training may enhance acceleration ability, its impact on anaerobic power parameters may be limited, with further research warranted to elucidate its efficacy comprehensively. The alpha level of 0.05 was used for significance testing, with the alternative hypothesis stating that the mean pre-test and post-test values are not equal.

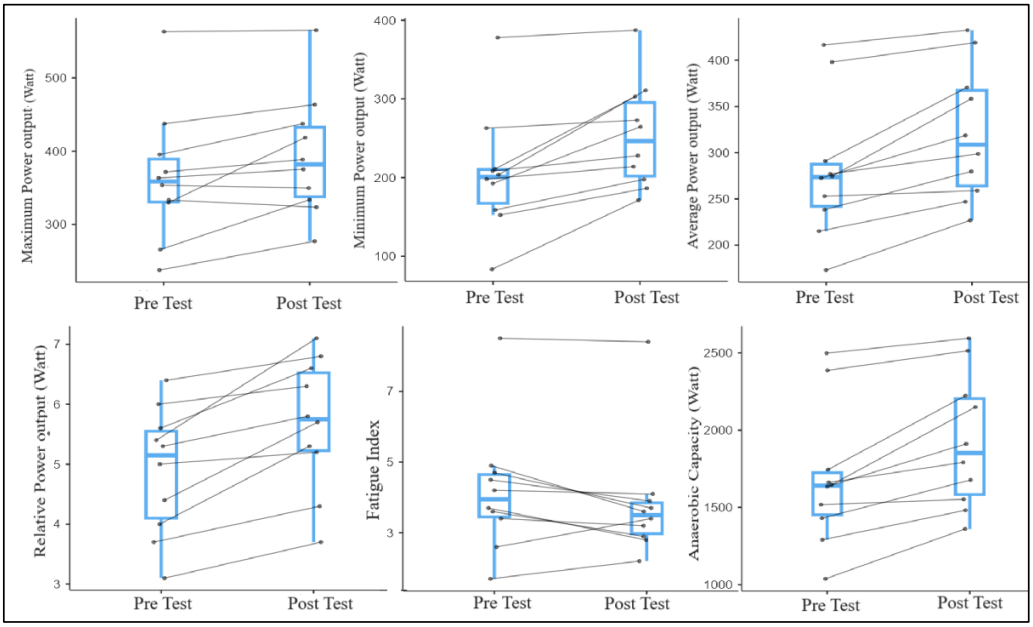

Fig. 3. Graphical comparison of Anaerobic Power output

Table 4. Effect prescribed interval training on acceleration ability and anaerobic power

Variables	Parameters	t	p	Mean difference	SE difference	Effect Size (Cohen's d)
Acceleration ability (m/s^2)	0-10 m	2.07	0.05	0.14	0.07	0.88
	10-20 m	2.39	0.03	0.25	0.11	1.02
	20-30 m	1.29	0.21	0.20	0.16	0.55
	30-40 m	0.36	0.73	0.09	0.24	0.15
	40-50 m	1.18	0.25	0.29	0.25	0.51
Anaerobic power (watt)	Ave. Power	-1.18	0.25	-40.28	34.11	-0.50
	Max. Power	-0.66	0.52	-26.35	39.95	-0.28
	Min. Power	-1.61	0.12	-52.91	32.84	-0.69
	Fatigue Index	0.71	0.48	0.54	0.75	0.30
	Relative Peak Power	-1.63	0.12	-0.78	0.48	-0.70
	Anaerobic Capacity	-1.18	0.25	-241.69	204.70	-0.50

Note. Level of significance: $\alpha \leq 0.05$, H_a: $\mu_{\text{Pre test}} \neq \mu_{\text{Post test}}$

Figure 3 depicts a graphical comparison of Anaerobic Power output before and after a four-week prescribed interval training regimen. The plot provides a visual representation of the impact of the training program on the rate of change of power output. The illustration exposes observable trends of power output before and after the intervention. This visualization serves to elucidate the effectiveness of the interval training program in enhancing Anaerobic Power, providing insights into the trajectory of improvement or any variations in performance throughout the intervention period.

Discussion

The demographic analysis of novice sprinters in this study indicates a relatively homogeneous group in terms of age, with participants being young adults. The height of the participants shows moderate variability typical for sprinters, suggesting consistency in factors like stride length and mechanics. However, body mass exhibits significant variability, indicating differences in muscle mass and body composition. Despite this, the mean Body Mass Index (BMI) suggests that participants generally maintain a slender physique characteristic of competitive sprinters. The training program did not lead to significant changes in body mass, indicating its ineffectiveness in altering body composition. This highlights the need for further research into more intensive or varied training protocols, possibly including dietary modifications, to achieve more substantial outcomes in body mass management and performance enhancement. The study's analysis of the cumulative time for the 50 m dash pre- and post-intervention provides valuable insights into the acceleration capabilities of novice sprinters. The intervention notably improved performance, particularly in the initial phase of the sprint, as evidenced by reduced times in covering the first 20 meters. This indicates enhanced speed due to the prescribed interval training protocol. Sprinting encompasses distinct phases: acceleration, locomotion, and deceleration. This finding corroborates earlier research indicating that early-phase acceleration responds more positively to targeted training interventions compared to subsequent phases, which may necessitate different training approaches (Mero et al., 1992; Weyand et al., 2000). The study observed enhanced initial acceleration within the first 20 m post-intervention but did not detect significant improvement in the later segments of the sprint, suggesting limited enhancement in locomotion and deceleration phases. Previous studies affirm that high-intensity interval training (HIIT) effectively enhances rapid acceleration, muscle power, and strength. HIIT protocols involving short bursts of maximal effort followed by rest periods enhance the recruitment and efficiency of fast-twitch muscle fibers critical for explosive starts (Burgomaster et al., 2008). Moreover, research demonstrates that such training improves neuromuscular coordination, thereby enabling more efficient and powerful movements during initial sprint phases (MacDougall et al., 1998). Additionally, interval training correlates with increased anaerobic capacity, enabling athletes to maintain higher speeds during acceleration (Laursen & Jenkins, 2002), while short, intense sprints enhance the neuromuscular system's capacity for rapid power output, crucial for acceleration (MacDougall et al., 1998).

The absence of significant improvement beyond 20 meters suggests that while the intervention enhanced quick-start capabilities, it was less effective in improving sustained speed or endurance over longer distances. Different sprint phases impose distinct physiological and biomechanical demands, emphasizing explosive strength for initial acceleration and speed endurance for maintaining velocity (Mero et al., 1992; Mujika et al., 1995). This finding aligns with previous research indicating that interval training can effectively enhance initial sprint acceleration (Weyand et al., 2000). However, no statistically significant improvements were observed in acceleration beyond 20 m. This suggests that while the training protocol enhanced short-distance sprinting capabilities, it may not have provided sufficient stimulus for improvements in longer sprint phases, such as locomotion and deceleration. From this perspective, a short-term interval training protocol with a limited variety of activities may not comprehensively address the requirements of each sprinting phase. Incorporating diverse training approaches, such as speed endurance drills and resistance training, could be essential to optimize performance across all phases (Delecluse, 1997).

Anaerobic power, defined as the ability to exert high-intensity force in a short duration, is crucial for sprinters. This type of power relies heavily on the anaerobic energy system, encompassing both the phosphagen (ATP-PCr) system and anaerobic glycolysis (Laursen & Jenkins, 2002). Components of anaerobic power measured using the Running-Based Anaerobic Sprint Test (RAST) indicate that the prescribed interval training protocol effectively enhanced various aspects of anaerobic power, crucial for short-duration, high-intensity activities like sprinting. Gibala and his associates (2006) conducted a study involving novice sprinters who participated in a fourteen days interval training program and concluded that repeated high-intensity efforts were effective in increasing anaerobic power, leading to notable gains in explosive strength and speed by improving the efficiency of the phosphagen system (Gibala et al., 2006). While trends towards improvement were noted in some parameters (e.g., Minimum Power), particularly with moderate effect sizes, this suggests that while the intervention showed promise in enhancing certain aspects of anaerobic power, the effects were not uniformly significant across all parameters measured. This variability in response may necessitate further optimization of training protocols tailored to enhance specific components of anaerobic power. Similarly, findings by Billat (2001) demonstrate that interval training significantly enhances anaerobic performance, making it an effective training strategy for novice sprinters (Billat, 2001). Conversely, Gharbi et al. (2015) indicated that a four-week HIIT program effectively increased peak and mean anaerobic power output in novice sprinters (Gharbi et al., 2015). The study underscores the importance of tailored training protocols that address the physiological demands of different sprint phases. While interval training proved effective in enhancing initial acceleration and certain aspects of anaerobic power, further refinement of training strategies may be necessary to optimize performance across all phases of sprinting. The prescribed interval training regimen demonstrated significant improvements in acceleration ability over short distances and various components of anaerobic power among novice sprinters, contributing to our understanding of targeted training interventions aimed at enhancing specific aspects of sprint performance. Future research should explore longer-term effects and the sustainability of these

improvements, as well as consider individualized approaches to maximize training adaptations in sprint athletes. Incorporating additional training modalities, such as speed endurance drills and resistance training, could potentially complement interval training and further enhance overall sprint performance (Naves et al., 2018).

Conclusions

The prescribed interval training protocol in this study proved effective in improving initial acceleration and specific components of anaerobic power among novice sprinters. However, its impact on sustained speed and endurance beyond initial phases of sprinting was limited. Future research should focus on investigating the long-term effects of such training interventions and exploring individualized approaches tailored to athletes' specific needs. Incorporating diverse training modalities, such as speed endurance drills and resistance training, alongside refined interval protocols, holds promise in achieving more comprehensive improvements across all phases of sprinting.

Acknowledgment

The authors acknowledge the support from Prof. Dr. Nandan Bhattacharya, Principal of Panskura Banamali College (Autonomous), and express gratitude to all the volunteers who participated in the study.

Conflict of interest

The authors declare no conflict of study for the study.

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Оцінка впливу короткотривалого інтервального тренування на показники здатності до прискорення та анаеробну потужність спринтерів-початківців

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Реферат. Стаття: 8 с., 4 табл., 3 рис., 17 джерел.

Історія питання. Здатність до прискорення та анаеробна потужність є критично важливими чинниками, що визначають результативність спринту, особливо для спринтерів-початківців.

Мета дослідження. Мета дослідження полягала у вивченні впливу чотиритижневої інтервальної програми тренувань на показники здатності до прискорення та анаеробну потужність серед спринтерів-початківців.

Матеріали та методи. Задля досягнення цілей дослідження було застосовано внутрішньо-суб'єктний квазі-експериментальний метод. Загалом п'ятнадцять учасників (вік: 20,5 ± 1,4 року) пройшли базову перевірку здатності до прискорення (біг на 50 м) та анаеробної потужності (тест на анаеробний спринтерський біг). Затверджений протокол прогресивних інтервальних тренувань складався з чотирьох щотижневих занять, що проводилися протягом чотиритижневого періоду, з акцентом на виконання ходьби, високого піднімання колін, стрибків на одній нозі, спринтерських забігів по кривій та стрибків на двох ногах з метою покращення показників здатності до прискорення та анаеробної потужності.

Результати. Після проведення інтервенції спостерігалося значне покращення здатності до прискорення на дистанції 10 м (до: 2,14 ± 0,16 с, після: 2,02 ± 0,14 с, $p < 0,05$, d Коена = 1,02) та 20 м (до: 3,47 ± 0,23 с, після: 3,32 ± 0,20 с, $p < 0,05$, d Коена = 0,78), що вказує на помірний та великий розмір ефекту. Однак не було встановлено жодних суттєвих поліпшень у показниках анаеробної потужності (середня потужність, максимальна потужність, мінімальна потужність, індекс втоми, відносна пікова потужність та анаеробна ємність) на етапі після інтервенції ($p > 0,05$).

Висновки. Дослідження підкреслює ефективність застосування протоколу інтервального тренування з точки зору покращення показників первинного прискорення у спринтерів-початківців, проте демонструє обмежений вплив на анаеробну потужність впродовж досліджуваного періоду. Подальші дослідження мають бути спрямовані на вивчення довгострокових ефектів та індивідуальних тренувальних підходів щодо оптимізації комплексних стратегій розвитку результативності в спринті.

Ключові слова: прискорення, анаеробна потужність, тест на анаеробний спринтерський біг, спортсмени.

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Cite this article as: Paria, P., Dhar, A., Biswas, A., & Biswas, S. (2024). Assessing the Effect of Short-Term Interval Training on Acceleration Ability and Anaerobic Power of Novice Sprinters. *Physical Education Theory and Methodology, 24*(5), 728-735. https://doi.org/10.17309/tmfv.2024.5.07

Received: 24.07.2024. Accepted: 09.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Environmental Psychological Characteristic Supporting the Football Player's Development in Indonesia and Malaysia

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Accepted for Publication: September 9, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.08

Abstract

Background. The development path of a football player toward becoming a professional player involves four main aspects: physical, technical, tactical, and psychological ones.

Objectives. This study aimed to examine the psychological characteristics of the environment that influence and contribute to the development of football players under 17 years old in Indonesia and Malaysia.

Materials and methods. This study used a qualitative approach, namely evolved grounded theory, and the data collection process was conducted using three distinct methods: semi-structured interviews, observation, and document analysis. Twenty-five coaches participated in this study, comprising fifteen coaches from various football academies in Malaysia and ten coaches from Indonesia. All coaches involved in this study have a license and at least five years of experience as coaches under 17. The data collected and analyzed began with open coding, axial coding, and selective coding, and the analysis was assisted by using qualitative research software, namely N-Vivo 14.

Results. The findings revealed that several aspects influenced player development, such as policy support, including structured and competitive age group competitions, a healthy football ecosystem; other results have been defined as relationships and cooperation supported by family, friendship between clubs, and teamwork. Finally, the study underscored the significance of involving coaching factors, including passion, patience, and coach psychological treatment abilities. These are the psychological characteristics of the environment that can influence the development of football players.

Conclusions. It is hoped that the results of this study can be used as a reference for coaches, the Indonesian Football Association, and the Malaysian Football Association to create a policy that can support football players under 17 years from all aspects, including psychology.

Keywords: environmental, psychological characteristic, football player.

Introduction

The aspect of player development is significant in football because the professional football club is concerned with the players' ethos since they are in a competitive league with an increasingly lucrative market (Bullough & Jordan, 2017). Football is not just a sport; it has a significant role in people's recreation, community building, and health, impacting the economy and social life (Orosz & Mezo, 2015). Therefore, it is widely acknowledged that younger football players have become more professionally trained to fill the demand for football (Gledhill et al., 2017). Talent development became of great interest to the national support governing bodies (Lauer et al., 2010). The coach often challenges players to prepare for the demands of modern performance situations (Sullivan et al., 2021). As demanded by the fans and supporters, it became their duty to find and build good performers. Other than that, emphasizing player development is significant because it can limit the negative consequences and harness the player's positive internal and external assets (Bean et al., 2018). Player development is influenced by the environment where the players grow and thrive, which is directly related to the roles coaches and other essential figures play (Marholz et al., 2016).

Regarding the demand and importance of player development, the process of player development in football is a complex thing to do. According to Sweeney

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et al. (2022), player development is influenced by various innate, psychological, and behavioral factors. Moreover, research on player development indicates the critical role of psychological and primarily social and cultural circumstances on player development (Larsen et al., 2012). In this case, many aspects related to the player's psychology, one of which was external factors. In this case, Gledhill et al. (2017) classify the player psychological factor into several aspects, and one of them is the external psychological factor, including autonomy, supportive coaching, parenting styles, coach-player relationships, an effective learning environment, and a talent development environment. This external factor was also known as the social support aspect or environmental psychological characteristic aspect. This factor is significant in football player development. It could influence the player's skill and technique. Ivarsson et al. (2020) stated that an appropriate environment for players could sharpen their decision-making and understanding and build a recognition pattern. Appropriate support will also provide a suitable environment and conditions where the player can compete pretty, which will then affect the player's psychological and skill development (Gledhill, 2016). Therefore, it was suggested that the significant variables of social opportunities be incorporated into the player training session to generate awareness among the possible stakeholders that could support the player's development (Hagen, 2011).

According to Orosz and Mezo (2015), a player's talent and development greatly depend on the psychosocial condition of the player. Player psychosocial conditions such as the training place, equipment available for training, and the players' involvement in their social condition are considered secondary factors in player development. However, they are still significant (Baker & Horton, 2004). According to Crawley and Hills (2023), elite youth football academies demand a unique psychosocial condition for the player. The players were posed to cope with specific environmental psychological characteristics, which the environment developed and shaped. It is crucial since it will promote standard but essential features such as communication, promotion of autonomy, and the holistic development of a solid and coherent organizational culture (Henriksen et al., 2010). This is why specific football academies are known to have a unique characteristic of playing football: they build a football culture. Other than that, the activities, behaviors, and support that the player learns and perceives through their environment could affect their technique and tactics (O'Connor et al., 2017). Therefore, psychosocial factors or environmental psychological characteristics are essential for player development.

The importance of environmental psychological characteristics should be a cause for concern among researchers and practitioners. This is because the support of environmental psychological characteristics will come from the academies and family, friends, environment, coach, and other possible aspects. Exploring this theme is essential since the external psychological support of the athlete often impacts enjoyment, engagement, performance, and well-being. It is also stated to contribute to adverse outcomes such as overtraining and burnout, damaged self-esteem, and affective disorders such as anxiety and depression (Richardson et al., 2022). In this case, Gledhill et al. (2017) stated that researchers and practitioners may find it easier to update and improve player development strategies with a deeper grasp of psychosocial aspects and how they affect them. However, research on this theme is scarce in Indonesia and Malaysia. Research related to the environmental psychological characteristics in Indonesia only related to the relationship between physical fitness, the psychosocial aspect, and the spiritual aspect among students in school (Nopembri & Sugiyama, 2022). Research on this theme in Malaysia is only related to challenges and psychological skill training (Khan et al., 2023), the psychological distress of esports players (Lee & Tam, 2024), and the influence or correlation of mobile phone use on students psychological aspects (Zulkefly & Baharudin, 2009). No research explicitly explores what kind and how the psychosocial aspect could influence player development among footballers in Indonesia. Therefore, based on the coach's perspective, the current research aims to explore the psychosocial aspect that influences football player development in Indonesia.

Material and Methods

Participants

The current research investigates the environmental and psychological characteristics influencing football players' development. A case study was employed to conduct a qualitative inquiry. Since the purpose of the research was to ascertain the participants' opinions regarding the fundamental components of grassroots football, purposeful sampling was considered while accounting for the participants' knowledge, experience, and competence. Two prerequisites for participation in the current study include a coaching license and at least five years of coaching experience. Twenty-five coaches participated in the study: fifteen from Malaysia and ten from Indonesia. The participant's data is included in Table 1 and Table 2.

Table 1. Malaysian Participant Information

No	Age	Level of Licence	Education	Coaching experience (year)	Status
JM1	41	D & Grassroot	Master	16	Active
JM2	43	B	Master	17	Active
JM3	42	B	Bachelor	18	Active
JM4	48	C	Bachelor	20	Retiring
JM5	39	A	Master	16	Active
JM6	46	C	Master	10	Active
JM7	59	A	Master	30	Active
JM8	65	A	Master	40	Active
JM9	68	C	Master	36	Retiring
JM10	54	B	Master	22	Active
JM11	30	C	Senior High School	7	Active
JM13	54	B	Master	28	Active
JM14	42	C	Bachelor	10	Active
JM15	35	A	Master	12	Active

Table 2. Indonesian participants

No	Age	Licence	Education	Coaching experience (year)	Status
JI1	30	C	Bachelor	10	Active
JI2	38	C	Bachelor	12	Active
JI3	31	C	Bachelor	6	Active
JI4	43	B	Bachelor	17	Active
JI5	53	B	Bachelor	16	Active
JI6	49	B	Bachelor	15	Active
JI7	42	A	Master	10	Active
JI8	45	B	Master	18	Active
JI9	36	A	PhD	13	Active
JI10	42	A	Senior High School	6	Active

Instruments

This study included a semi-structured interview to grasp the participants' perspectives thoroughly. In this case, the researcher developed and validated the interview procedures and questions. The instrument validation considers both face and content validity through the use of Cohen kappa analysis. Ten specialists assessed the tool employed in this research. There were four experts in qualitative research, four in football, and two in psychology. The Cohen kappa analysis on the expert rating was then used to assess the instrument's appropriateness with the theme under investigation in this study. The established criterion for evaluating the Cohen kappa was the Landis and Koch (1977) technique (<0.00 = extremely weak, 0.00-0.20 = weak, 0.21-0.40 = relatively weak, 0.41-0.60 = suitable, 0.61-0.80 = good, and 0.81-1.00 = very good). Table 3 displays the validation result.

Ethical Consideration

In order to be in charge of research ethics, the Sultan Idris University of Education's Research Ethics Committee approved this study (UPSI). The research ethics committee suggested and implemented several adjustments. The researcher then made any required adjustments to secure ethical approval. After several adjustments and revisions, the ethical approval was approved on May 15, 2023.

Analysis

The main method of data collection for this qualitative study was interviews. The data collected for this study was examined using the qualitative analysis application N-Vivo 14. According to Williamson and Long (2005), when evaluating data in qualitative research, specific procedures, including selecting, abstracting, and modifying the raw data—that is, its initial coding and theme search—should be adhered to. N-Vivo software helped with every procedure in our investigation. The investigator first loads all raw interview transcripts into the N-Vivo program. The second researcher selected the data. Due to the interview's semi-structured format, several chats and exchanges veered off-topic. Consequently, the investigator deliberately selected a subject or conversation to tackle the fundamental components of the athlete's psychological component. Third, researchers abstract and translate the basic data into specific code using various N-Vivo software tools. Determining the most frequently discussed topics or phrases is helpful.

Results

Researchers spent at least ten months completing this research process, which began with the process of preparing questions for interviews, the interview process, data transcription to data analysis, which was carried out repeatedly to find themes that would explain the appropriate form of parental support for children as football players at this level of grassroots football. The researcher first explains the data collection process in this research, which has provided information regarding the research results.

Interview

The current research explores environmental psychological characteristics that might influence football player development. The coach's perspective, in this case, was explored to reveal the environmental and psychological characteristics needed for player development. N-Vivo, a program for qualitative data analysis, was used to examine the information gathered from the coaches. The document was configured prior to the N-Vivo analysis. In order to allow the N-Vivo to concentrate on examining the interviewee's viewpoint and opinion, the interviewer's question was removed from the document. As a result, N-Vivo identified three main factors affecting the athlete's development based on the coach's perspective: policy, family, and coach support.

The Policy Support

Policy support refers to how the program or academy creates holistic support for athlete development in terms of the player's physical, mental, and technical development. Player development is not only solely concerned with the athlete but also with the supportive ecosystem. It could provide a development pattern for the athlete with a specific and clear curriculum and psychological support. As one of the coaches stated.

Table 3. Cohen Kappa Result

Expert A	Expert B	Expert C	Expert D	Expert E	Kappa Coefficient Min
$K_1 = \frac{25\text{-}12.5}{25\text{-}12.5}$	$K_2 = \frac{24\text{-}12.5}{25\text{-}12.5}$	$K_3 = \frac{23\text{-}12.5}{25\text{-}12.5}$	$K_4 = \frac{22\text{-}12.5}{25\text{-}12.5}$	$K_5 = \frac{25\text{-}12.5}{25\text{-}12.5}$	$K = \frac{K_1+K_2+K_3+K_4+K_5}{5}$
1.000	0.920	0.840	0.760	1.000	0.904

> "You need to create a pattern that could derive these players in the positive direction of their development. It is because they still need psychological support in order to be mature players. It has already been done by great clubs and academies in Europe; their academy and ecosystem were initiated to force the player in a positive pattern" (JI7).

In this case, the football academy has a vital role in supporting player development in terms of psychological development, even through the primary and regular program in the academy. For example:

> "Our academy has a bus to transport the players and staff. Through this, we think we can give them an example of how teamwork and responsibility work. We obligate them to come on time before departure, and we cannot go without all the players there" (JM7).

That is an example of how the academy could initiate a positive psychological example that supports player development inside and outside the field. Other than that, the coach and staff also can initiate the regulation or rule for the player.

> "We need the player to have good manners in their social interactions. For example, focusing on the phone is bad manners when sitting down with others. So we taught them that no phone was allowed when the dinner was at the dining table" (JM9).

This is a simple but very important step for the player. In addition, the player needs to be taught how to behave and use positive psychology during the game.

> "In the exercise, I like the player to play football directly. It is to train them about the competition, where during the game they should have a fighting spirit and motivation to win even in the training section" (JM8).

> "Competitive feeling is important; it is a criterion for a professional player. Not competitive on the money, but competitive on enhancing their performance in the field, and competitive on achievement" (JM3).

With sufficient support from the academy, the player's competitiveness can be developed during training. In this case, the academy can initiate positive competition regulation among the players, which is very important to developing not only player skills but also discipline, punctuality, and responsibility for their duties.

> "In the training section, we value the player's achievement, whether they attain the given objective. We also value the player's competitiveness individually, not in a group. This is very important, where we as coaches and staff can understand the player's difficulties and problems so we can adjust the training and help the player" (JI9).

That is how the academy initiates a favorable ecosystem for the player, which is crucial for player development.

> "What was exactly needed by the player's psychological development was having a positive place and ecosystem to compete and train" (JI7).

In addition to the academy's internal support, collaboration and support from alumni and seniors are also important for the player. They could give the player a positive example, which could trigger their motivation.

> "Player maturity in football results from research, learning, exercise, and the positive psychological ecosystem experienced by the player. The seniors give me such a positive vibe and example, so I learn from them" (JM4).

> "When the player looked at their senior, who got a salary of around RM40.000 to RM80.000, the senior told the player that in the past, they were the same as the player with a similar program, a similar field, similar coaches, and a similar dormitory" (JM15).

This program also generates positive psychology in the player, where the senior gives motivation and examples on how to behave and train.

The relational cooperativeness

To be a good player, support and cooperation are essential for their development. The current research found that support from the athlete's environment and family can help the player's development. It is essential to give psychological support, such as motivation and the belief needed to face the challenges.

> "I observe that the players who received support from their parents have better career and development compared to the players who do not. I 100% believe the player needs support from their family and parents. Without support, how could they face the challenges during their development?" (JM11).

Support is not a big deal; it is a simple way for the family to help athletes in their environment.

> "Many players here got support from their families; the family is watching the game, bringing snacks and water, and giving a simple reward to the athletes if they win" (JM4).

Family support can make sure the player is on the training schedule.

> "The support and assistance from the family is significant. For example, Ayman Ari and Zikri are both from Kuantan and trained in Balung. Their mothers always accompany their children to the training center every Monday, Wednesday, and Saturday" (JM5).

Family support is important not only for driving by and giving something to the player but also for providing psychological support.

> "In my opinion, the family is much affecting the player's development; the parents should provide essential education, understanding, and motivation to the player. The parents have a greater chance to control the player regarding eating, resting, playing, and training. The parents should motivate and remind the player regarding their schedule, etc." (JI3).

Supporting is not only related to giving psychological motivation but also creates a competitive environment for the athlete.

> "The environment, such as family and close friends, should support the player. A supportive environment is needed in order to create a competitive situation for the athletes" (JM2).

The coach support

There is no doubt that the coach's support is essential. They are the ones who have responsibility for the player's development. Therefore, the coach hopes to understand how to maintain the player's motivation, spirit, and encouragement.

> "The important aspect was the psychology, which can encourage the players. We, as coaches, should emphasize having spirit and resistance. If the player loses, we should motivate them and try to enhance their mood. So, currently, the coach has an important role in keeping the player on track. One example was to insist on the perspective that even though they were lost, at least they created a chance and a goal, which was still great. I think that is important since we should give the player a reward (even small)" (JM1).

The coach should insist on positive motivation for the athletes and not disappoint them.

> "The coach should enhance the positive psychological aspect of every training. We should create their self-efficacy and self-belief every time. Whatever their progress, we should appreciate them. Do not always blame them; give them bad credit and too much push for them. As the coach, we should focus on the player's positive psychology and motivation" (JM14).

It is true that the coach is not only responsible for the player's physical and technical skills but also their mentality.

> "I believe that the coach not only rules the player technique but also the player mentality. That is their responsibility. It is because they are the ones who interact with the player personally" (JI2).

Therefore, supporting the player's mentality and psychology is one of the coach's jobs.

> "The coach has responsibility for the player's mentality. The player cannot be left alone; they need friends they can share with, understand their problems, and consult with. They need someone who can remind them and solve the problem. If they decide and do something wrong, it is the coach's responsibility to remind the player" (JI8).

In this case, the coach should know how to interact positively with the players and help them create a good environment.

> "The coach should have knowledge of training, such as how to communicate with the player and understand the gap between the coach and the player. The coach knows when to be serious, fun, and enjoy. This is what is very needed" (JM13).

It is important since good communication and interaction between the coach and player can build trust so the player can obey the role, love the training, and love to play football.

> "We build trust and confidence between the player and coach. As coaches, we should trust the players so they will trust us. Then, the player will obey the rule and any training material provided" (JM10).

> "First, I inform the player that the club trusts you, so give your best. Coach, give instructions, and you are the king in the field" (JM4).

Many ways to keep students motivated. There are numerous options available to the coach.

> "One day, I plan for the player to meet with VI (one of the best and most famous footballers). I told the players that if they want to meet with VI, they should train sufficiently, hardly because he is the best player. I told them that I was on one team with VI. He was very disciplined, sincere, and patient in his training. That is what made him a champion" (JM6).

Discussion

The current research explores the environmental psychological characteristic that impacts the player's development. The coach's perspective was considered the primary data resource in this case. Ten coaches were interviewed, and the data were analyzed through qualitative analysis software, namely N-Vivo. Based on the result, three essential supports are needed for player development. The first is policy support, the second is family support, and the third is coach support.

Regarding policy support, the current research found that through the rules and regulations of the academies, patterns of the student's behavior and activities can be formed, such as their manner, behavior, mentality, as well as their decision-making, competitiveness, and discipline. Policy support, also known as organizational support, values the player's contribution and achievement and is concerned with the player's self-esteem (McLeod et al., 2022). It is essential since it relates to the landscape of how the club or the academies will operate (Bullough & Coleman, 2019). For example, the activities, program, training procedure, and schedule. In this case, Morley et al. (2014) stated that player development in football is inferred from the fact that the player is provided with an appropriate learning environment to translate their potential into excellence. An appropriate environment will allow the nurturing of talent, which can help the player progress and play as a professional. Therefore, the academy or club rule is significant for player development.

The second factor was relation and cooperativeness. The current research found that the family has a role in player development in terms of psychological and financial support as well as educating and motivating the player. In this case, other research also emphasized the significant impact of family support on player development. Hellstedt (2005) stated that the family is essential for the player; it is where the player develops their skills and coping mechanisms in facing challenges, competition, and training. This is because the family can have three roles in player development: provider, interpreter, and role model (Weiss, 2004). In terms of the provider, the parents should give the player a chance to explore and experience the sport and invest their money and time (Lauer et al., 2010b). Lauer et al. (2010a) stated that the parents or family have an integral role in player development, where the parents shape the pursuits that kids make early in life and offer the chances and materials required to support their growth. With the backing of strong parents early on in their involvement in sports, players are likely to reach their full potential (Wolfenden & Holt, 2005). Therefore, parents can boost the chances for children to have a positive psychological experience, develop a range of positive developmental outcomes, and achieve their sporting potential (Dohme et al., 2020).

The third factor was the coach's support. The current research found that despite the role of sport in the player's physical development, the coach also has essential rules for player psychological development in terms of spirit and resistance, self-efficacy, self-belief, mentality, confidence, and trust. Studies highlight coaches' crucial role in implementing developmentally appropriate programs that center around enhancing personal resources and strengths (Vella et al., 2011). Research supporting this interpretation of the function of coaches has demonstrated that training and assistance for youth sports coaches can increase the chance of positive kid development (Smoll et al., 1993). By seizing naturally occurring instructive opportunities, coaches can promote positive developmental outcomes from both team success and team failure. This is because they can foster healthy, developmentally appropriate coach-athlete relationships and provide intellectual stimulation, individual attention, and positive role modeling (Vella et al., 2013). Besides that, the coach is the leading actor in player development (Ford et al., 2010). They are the ones who directly interact with and train the player.

Conclusions

This research explores the environmental and psychological characteristics that affect player development in Indonesia. Qualitative methods, namely interviews, were used

to collect the data. Fifteen coaches from various football academies in Malaysia and ten coaches from Indonesia were interviewed. They were asked about the environmental psychological characteristics that could influence the player's development. The data collected was analyzed with qualitative research software, namely N-Vivo 14. The results revealed several aspects that influence player development, namely the policy factor, the family factor, and the coach factor. These environmental and psychological characteristics could influence football players' development.

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Психологічна характеристика оточуючого середовища як чинника сприяння розвитку футболістів в Індонезії та Малайзії

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 3 табл., 34 джерела.

Історія питання. На шляху становлення футболіста як професійного гравця можна виокремити чотири основні аспекти: фізичний, технічний, тактичний і психологічний.

Мета дослідження. Метою цього дослідження було вивчити психологічні характеристики оточуючого середовища, які визначають та сприяють процесу розвитку футболістів віком до 17 років в Індонезії та Малайзії.

Матеріали та методи. У даній роботі було застосовано якісний дослідницький підхід, зокрема розвинена обґрунтована теорія, процес збору даних проведено із використанням трьох окремих методів: напівструктуровані інтерв'ю, спостереження та аналіз документів. У дослідженні взяли участь двадцять п'ять тренерів, з яких п'ятнадцять тренерів представляли різні футбольні академії Малайзії та десять тренерів з Індонезії. Усі тренери, залучені до цього дослідження, мали ліцензію та щонайменше п'ять років досвіду роботи тренером у віковій групі до 17 років. Збір та аналіз даних розпочався з відкритого кодування, осьового кодування та вибіркового кодування, а в процесі аналізу використовувалося програмне забезпечення для якісних досліджень, а саме N-Vivo 14.

Результати. Результати дослідження показали, що на становлення розвитку гравців впливають такі аспекти: політика підтримки, що включає структуровані та конкурентоспроможні змагання у вікових групах, сприятлива футбольна екосистема; інші результати були визначені як відносини та співпраця, що підтримуються сім'єю, дружні взаємозв'язки між клубами та робота в команді. Наостанок підкреслена важливість врахування тренерських чинників, зокрема захопленості до своєї справи, терпіння та вміння тренера надавати психологічну допомогу. Саме такі психологічні характеристики оточуючого середовища можуть впливати на рівень розвитку футболістів.

Висновки. Очікується, що результати цього дослідження можуть слугувати орієнтиром для тренерів, Індонезійської футбольної асоціації та Малайзійської футбольної асоціації у створенні політики підтримки футболістів віком до 17 років на рівні всіх аспектів, включаючи психологію.

Ключові слова: оточуючий, психологічна характеристика, футболіст.

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Cite this article as: Akbar, A., Karim, Z. A., & Zakaria, J. (2024). Environmental Psychological Characteristic Supporting the Football Player's Development in Indonesia and Malaysia. *Physical Education Theory and Methodology, 24*(5), 736-743. https://doi.org/10.17309/tmfv.2024.5.08

Received: 24.07.2024. Accepted: 09.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Beyond the Finish Line: Muscle Injuries in Athletic Competition

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Accepted for Publication: September 9, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.09

Abstract

Objectives. The study aimed to compare the incidence of muscle injuries in the qualifying rounds, semifinals and finals in athletics.

Materials and methods. A total of 14 male and 12 female athletes who participated in all rounds (preliminaries, semifinals, and finals) of the 100 m, 200 m, and 400 m matches were analyzed over a 4-year period starting in 2021-2024. The female athletes were aged 22.4 ± 3.81 years, with a mean height of 167 ± 8.6 cm, and weight – 64.6 ± 17.5 kg. The male athletes were aged 23.4 ± 3.82, having an average height of 169 ± 8.3 cm, and weight – 66.4 ± 15.8 kg. A t-test was used to conduct comparative assessment of performance between finals, semifinals, and preliminaries for each gender and event. A 95% confidence interval was calculated separately for each gender, event, and round. Additionally, incidence rates were compared. The significance level was accepted at $p < 0.05$.

Results. HMI (hamstring muscle injuries) incidence rate for female qualifiers was found to be 1.50 (1.05-1.95), semifinals – 1.33 (0.79-1.88), and the final – 1.91 (1.44-2.38). LLMI (lower limb muscle injuries) incidence rate among female qualifiers was 1.50 (0.58-2.42), semifinals – 1.00 (1.00-1.00), and the final – 1.55 (1.36-1.74). HMI incidence rate in male qualifiers was 0.50 (0.08-1.28), semifinals – 0.67 (0.77-2.10), and 1.00 (0.34-1.66) in the final. LLMI incidence rate for male qualifiers was 0.40 (0.28-1.08), semifinals – 0.24 (0.55-1.05), and the final revealed 0.60 (0.08-1.28).

Conclusions. The highest incidence of muscle injury in all forms among men was observed in the all-round category. In women, hamstring muscle injuries occurred in the final, while lower limb muscle injuries were most prevalent in the preliminaries and semifinals.

Keywords: athletic, track and field, injuries, competition.

Introduction

Most injuries in athletic championships are to the thigh (26.2%), lower leg (17.3%), or knee (10.7%), with hamstring tear being the most reported injury (14.9%) (Boltz et al., 2021). Hip and thigh injuries were the most commonly injured body regions in NCAA track and field championships, with different injury types depending on the event (Hopkins et al., 2022). Track and field athletes commonly experience knee (28%) and shoulder (14%) injuries, with time loss in sporting activity being longest in the knee region (26 weeks) (Lambert et al., 2022).

Sports injuries can lead to abnormal physiological or psychological stress responses, which may challenge athletes' ability to continue their sports careers at a competitive level (Yang et al., 2022). Acute traumatic sports injuries can harm an athlete's performance based on their perception of the severity of the injury, but this decline in performance and decrease in confidence does not correlate to their desire to leave their sport or their athletic identity (Laurel et al., 2023). Injuries in high-performance athletes can lead to forced suspension of training or competition, preventing performance improvement and decreasing career quality (Sun, 2023).

Based on previous research, (Pembayun et al., 2023) data did not have a normal distribution and no significant differences in injury management perception based on factors. Lack of skilled techniques leads to 89% of injuries and iImportance of mastering technical movements in track and field (Hu, 2021). No standard criteria for medical facilities for elite athletes and lack of exact procedure for treating elite athlete health problems (Rahayuni, 2020).

This study focuses on a specific athletics competition, the Central Java Open, which may not have been studied before in the context of muscle injuries. This study compares muscle injury rates between three crucial competition stages, namely the qualifying, semi-finals and finals, which could provide new insights into injury patterns in athletic competition. By understanding the risk factors that arise in different competition contexts, coaches and athletes can design more effective training and recovery strategies to achieve optimal performance. In addition, the results of this study

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can contribute to the development of better sports policies related to athlete safety, as well as enrich the scientific literature on sports injuries and their influencing factors.

Materials and Methods

We conducted a thorough analysis of athletes who participated in running competitions. We did not include: 1) single-round disciplines and events (such as sprint and marathon), since it was not feasible to compare the results of the finals with those of earlier rounds; and 2) relay, 400-meter races, throwing, and jumping. There was no parental or public participation in this study. All injury reports were gathered manually and through Google Forms.

The same study design, injury definition, and data collection methods – all of which have been thoroughly detailed previously – were used to collect all of the data prospectively. According to de Sire (2022) injuries were classified as musculoskeletal symptoms that cropped up during training or competition and required medical attention. If an injury satisfied any of the following requirements, it was included in the analysis:

1. Took place in the sprints of 100, 200, and 400 meters.
2. Happened either during the competition or the warm-up (training injuries were not included).
3. Affected the lower leg, ankle, foot, knee, hip, groin, or thigh.
4. Were categorized as "muscle cramp/spasm" or "muscle strain/tear".

We counted how many athletes began each round. The athletes' performances resulted in medals obtained from the championship ranking results, and the events were semifinals and finals. Using a t-test, we compared results for each gender and event between the finals, semifinals, and preliminary rounds. For every gender, event, and round, we computed the degrees with a 95 % confidence interval independently. Incidence rates were compared. At $p < 0.05$, significance was deemed to exist.

Result

A total of 14 male and 12 female athletes who participated in all rounds (preliminaries, semifinals, and finals) of the 100 m, 200 m, and 400 m matches were analyzed over 4 years starting in 2021-2024 (Table 1-4).

Table 3. Comparison of Injury Incidence Rates

Variables	Sig.	Mean (lower-upper)
Relative risk of HMI occurrence		
Female Athlete		
Qualifiers vs Semifinal	0.994	0.167 (0.77-1.10)
Qualifiers vs Final	0.647	0.409 (-1.22-0.40)
Semifinal vs Final	0.378	0.576 (-1.46-0.31)
Male Athlete		
Qualifiers vs Semifinal	1.000	0.067 (-1.35-1.22)
Qualifiers vs Final	0.846	-0.400 (-1.45-0.67)
Semifinal vs Final	0.958	-333 (-1.58-0.91)
Relative risk of LLMI occurrence		
Female Athlete		
Qualifiers vs Semifinal	1.000	0.000 (-1.06-1.06)
Qualifiers vs Final	0.862	0.500 (0.83-1.83)
Semifinal vs Final	0.791	0.500 (0.65-1.67)
Male Athlete		
Qualifiers vs Semifinal	0.986	-0.267 (-1.55-1.02)
Qualifiers vsFinal	0.513	-0.600 (-1.67-0.47)
Semifinal vs Final	0.344	-0.350 (-1.53-0.83)

Table 4. Similarity of Injury Averages

Category	Sig.	Conclusion
Female	0.119	Does not have a significant difference
Male	0.384	Does not have a significant difference

Discussion

This research contributes to the literature on injury management in competitive sports, particularly in competition. It can provide practical guidance for coaches, managers, and athletes to improve athlete health and performance. The rate of muscle injury between the semi-finals and finals in track and field may differ due to various factors such as the intensity of competition, athlete fatigue, and the specific demands of each event. Research has shown that muscle injuries are common in track and field competitions, with a significant proportion affecting the thigh and lower leg (Bernuzzi et al., 2014; Edouard et al., 2016; Palmer et al., 2022). Additionally,

Table 1. Research Profile Characteristics

Category	Age	Height	Weight	1st Place	2nd Place	3rd Place	Homogenity
Female Athletes	22.4 ± 3.81	167 ± 8.6	64.6 ± 17.5	2	6	2	0.109 > 0.05
Male Athletes	23.4 ± 3.82	169 ± 8.3	66.4 ± 15.8	5	3	6	0.925 > 0.05

Table 2. Total injury incidence rate

Variables	Number of injuries	HMI	HMI incidence rate (95% CI)	LLMI	LLMI incidence rate (95% CI)
Female					
Qualifiers	18	12 (0.535)	1.50 (1.05-1.95)	6 (0.577)	1.50 (0.58-2.42)
Semifinals	20	8 (0.516)	1.33 (0.79-1.88)	12 (0.535)	1.00 (1.00-1.00)
Final	24	21 (0.701)	1.91 (1.44-2.38)	3 (0.000)	1.55 (1.36-1.74)
Male					
Qualifiers	5	3 (0.548)	0.50 (0.08-1.28)	2 (0.548)	0.40 (0.28-1.08)
Semifinals	3	2 (0.577)	0.67 (0.77-2.10)	1 (0.500)	0.24 (0.55-1.05)
Final	9	6 (0.632)	1.00 (0.34-1.66)	3 (0.567)	0.60 (0.08-1.28)

injury patterns vary between different athletic disciplines, with sprints, hurdles, jumps, and combined events being particularly prone to thigh muscle injuries (Edouard et al., 2016, 2020; Pinheiro et al., 2022). Moreover, male athletes have been found to have a higher risk of muscle injuries compared to female athletes, especially in explosive power events (Edouard et al., 2016). These findings suggest that the transition from semi-finals to finals, characterized by increased pressure and exertion, may contribute to a higher rate of muscle injuries in track and field athletes.

Higher physical intensity during finals matches may contribute to higher injury rates, as starters need to be physically prepared for greater match demands (Palmer et al., 2022). Higher physical intensity is associated with increased lower-body neuromuscular fatigue, which can lead to injuries (Meng & Qiao, 2023; Piedra et al., 2021). Psychosocial factors like perceived availability of informational support and time out of sport are associated with lower re-injury risk in competitive athletes (Gledhill & Craig, 2021). Stress and anxiety are significant factors influencing the risk of injuries, injury frequency, and injury severity in athletes (Chyi et al., 2023).

Women are more prone to injuries than men due to biological, anatomical and mechanical differences as well as social and economic factors that affect the level of risk (Kutaish et al., 2022). Female athletes have higher rates of severe injuries especially in lower extremities such as ankle and knee with gender-related anatomic/biomechanical disparities in the anterior cruciate ligament being a major contributor to this trend (Bradsell & Frank, 2022). Research about female service members indicates higher reported injury rates for women than men due to possible differences in fitness levels and injury reporting behavior among basic trainees (Schram et al., 2022).

Hamstring muscle injuries (HMI) occur more frequently than lower leg muscle injuries due to various factors highlighted in the research. Studies have shown that HMI are prevalent in sports like football and athletics, with risk factors including high-speed running exposure, previous injury history, and inadequate rehabilitation (Chu & Rho, 2016; Haddad et al., 2023; Moreno-Perez et al., 2024). The morphological and biomechanical characteristics of the hamstrings, such as heterogeneous loads under tension, gradient compliance between tissues, and multi-functional movement risks, contribute to the susceptibility of these muscles to injury, particularly near tendon-bone junction sites (Shi et al., 2022). Additionally, inadequate decision-making, nonadherence to rehabilitation practices, and insufficient evidence-based management strategies may also play a role in the increased incidence and recurrence of HMI in athletes, emphasizing the need for better injury prevention and rehabilitation protocols in sports medicine.

Injury management at the semifinal and final stages is crucial, as only two-thirds of athletes return to play at the same level as pre-injury (Carmont et al., 2020). In-competition injury during a combined events competition was associated with lower odds of winning a medal, suggesting injury prevention could contribute to improved performance success (Edouard et al., 2021).

To reduce the risk of injury in the semifinals and finals, several strategies can be implemented based on the findings from the research papers. Strength training has been recognized as an effective method to minimize the risk of sports injuries (Gonzalo-Skok, 2022). It is also crucial to consider the scheduling of matches to prevent players from experiencing fatigue and potential injuries due to prolonged play durations (Tristan et al., 2006). Furthermore, implementing proper warm-up routines and injury prevention programs, especially those tested for effectiveness, can significantly reduce the risk of injuries during crucial matches (Mącznik et al., 2021). By combining these approaches, athletes can enhance their physical resilience and decrease the likelihood of injuries during the intense competition of semifinals and finals.

The findings from this study may only apply to the Central Java Open or similar athletic competitions in the same geographic area or context. Generalization of these results to other competitions or in other venues may require additional research. Competitions such as the Central Java Open may have certain environmental or organizational factors (e.g., weather conditions, facilities, or race regulations) that may affect muscle injury rates. This study may not be able to consider all these contextual factors in detail.

Conclusion

The highest rate of muscle injury in men in all forms of injury was in the allround. In women, hamstring injuries occurred in the final, and lower limb injuries in the preliminaries and semifinals. The most common injury is a hamstring muscle injury. However, the difference in injury incidence rates between the rounds was insignificant. This study highlights several factors that may contribute to the high injury rate in the final stage, such as the higher intensity of competition, physical fatigue that begins to accumulate, or psychological factors that affect athlete performance.

Conflict of interest

All authors declare no conflict of interest.

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За фінішною межею: М'язові травми у змаганнях з легкої атлетики

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Реферат. Стаття: 5 с., 4 табл., 32 джерела.

Мета дослідження. Мета дослідження полягала в порівняльному аналізі поширеності м'язових травм у кваліфікаційних раундах, півфіналах та фіналах змагань серед спортсменів з легкої атлетики.

Матеріали та методи. Загалом було проаналізовано дані 14 спортсменів-чоловіків та 12 спортсменок-жінок, які брали участь у всіх раундах (попередніх, півфінальних та фінальних) змагань з бігу на 100 метрів, 200 метрів та 400 метрів впродовж 4-річного періоду, починаючи з 2021-2024 років. Вік спортсменок-жінок становив 22,4 ± 3,81 роки, середній зріст – 167 ± 8,6 см, а вага – 64,6 ± 17,5 кг. Вік спортсменів-чоловіків становив 23,4 ± 3,82 роки, середній зріст – 169 ± 8,3 см, а вага – 66,4 ± 15,8 кг. З метою проведення порівняльної оцінки результатів між фіналом, півфіналом та попередніми змаганнями для кожної статі та виду спорту використовувався t-критерій. 95 %-й довірчий інтервал розраховували окремо для кожної статі, виду спорту та раунду змагань. Крім того, порівнювалися показники поширеності травматизму. Рівень значущості становив $p < 0,05$.

Результати. Показник поширеності травм підколінного сухожилля серед спортсменок-жінок у відбіркових змаганнях становив 1,50 (1,05-1,95), у півфіналах – 1,33 (0,79-1,88) та у фіналі – 1,91 (1,44-2,38). Рівень поширеності травм м'язів нижніх кінцівок серед спортсменок-жінок у відбіркових змаганнях становив 1,50 (0,58-2,42), у півфіналах – 1,00 (1,00-1,00), а також у фіналі – 1,55 (1,36-1,74). У спортсменів-чоловіків показник поширеності травм підколінного сухожилля у відбіркових змаганнях становив 0,50 (0,08-1,28), у півфіналах – 0,67 (0,77-2,10) та 1,00 (0,34-1,66) у фіналі. Показник поширеності травм м'язів нижніх кінцівок серед спорстменів-чоловіків у відбіркових змаганнях становив 0,40 (0,28-1,08), у півфіналі – 0,24 (0,55-1,05), а у фіналі склав 0,60 (0,08-1,28).

Висновки. Найвищий показник поширеності м'язових травм всіх типів серед чоловіків спостерігався в категорії багатоборства. У жінок травми підколінного сухожилля зустрічалися на етапах фіналу, тоді як травми м'язів нижніх кінцівок були найбільш поширеними у попередніх та півфінальних змаганнях.

Ключові слова: спортивний, легка атлетика, травми, змагання.

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Cite this article as: Rumini, Adi, S., & Kusuma, D. W. Y. (2024). Beyond the Finish Line: Muscle Injuries in Athletic Competition. *Physical Education Theory and Methodology, 24*(5), 744-748. https://doi.org/10.17309/tmfv.2024.5.09

Received: 29.07.2024. Accepted: 09.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fizičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

The Integral Assessment of Playing Tactics in National Football Teams

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Accepted for Publication: September 9, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.10

Abstract

Objectives. The objective of the study was to determine the features of competitive activities among national football teams based on the integral assessment of playing tactics.

Materials and methods. The study was conducted during the 2024 European Football Championship. The competitive activities of national football teams from European countries (Germany, Spain, England, Switzerland, France, Portugal, Netherlands, Turkey) were analyzed, focusing on the playing tactics in 50 halves. In order to carry out the study, the following methods were used: theoretical analysis of literature sources; pedagogical observation of competitive activities; analysis of video materials of competitive activities; methods of mathematical statistics. The statistical analysis of the research results was conducted using descriptive mathematical statistics. The sample was characterized by determining the arithmetic mean, standard deviation (S), and coefficient of variation (V). The significance of observed differences in the indicators was assessed using the parametric Student's t-test for independent samples. Prior to this, the data's conformity to a normal distribution was verified using the Shapiro-Wilk W-test.

Results. A methodology for the integral assessment of the tactics undertaken by national football teams was developed. The integral assessment of team tactics consisted of 10 specific coefficients that reflect the main components of football players' competitive activities in the phases of ball possession and recovery. The competitive activities in 50 halves of the 2024 European Football Championship were analyzed. The average value of the integral assessment of the tactics in national football teams was determined to be 5.62 ± 0.43 points. The findings revealed significant tactical variations between the teams, with Spain's use of high pressing and creative play contributing to their championship victory. A ten-point scale for evaluating the tactics of national football teams was developed, on the basis of which the level of competitive activities is interpreted.

Conclusions. The developed methodology for monitoring and analyzing the tactics of football teams allows for targeted management influences on the competitive activities of football players at the operational, current, and stage levels.

Keywords: football, national teams, competitive activities, playing tactics, integral assessment, methodology, scale, monitoring.

Introduction

Football is not only the most popular sport, but also one of the most complex team sports, where competitive activities require a high level of technical, tactical, physical, and psychological preparedness (Qing Yi et al., 2018; Mola & Shaw, 2024). One of the most challenging problems in football is the control of competitive activities, which comprehensively evaluates the technical-tactical and physical preparedness along with the intellectual, mental, and psychological abilities of players (Kostykevich, 2019; Modric et al., 2019; Aquino et al., 2020).

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ТМФВ
ТОВ ОВС

The methodology for controlling and analyzing competitive activities in team sports has become the subject of scientific research by many scholars (Bezmylov, 2015; Mitova, Sidorenko, 2015). In particular, research on this issue has been conducted in basketball (Voznyuk et al., 2020; Bezmylov et al., 2024); volleyball (Shchepotina et al., 2020; Oliinyk et al., 2021); handball (Tyshchenko, et al., 2019; Solovey O., et al., 2020); ice hockey (Shynkaruk & Serebriakov, 2021); and field hockey (White & MacFarlane, 2015; Konnov, 2021; Kostiukevych et al., 2020). Regarding football, it is worth noting that the control and analysis of competitive activities in this sport are predominantly based on the integral assessment of technical-tactical activities (Shchepotina et al., 2021; Kostiukevych et al., 2022) and the monitoring of the attacking actions of football teams (Kostiukevych et al., 2020).

Thus, the analysis of literature sources allows us to determine the importance of the problem of controlling and analyzing the competitive activities of athletes in team sports, including football. At the same time, the problem of controlling the tactics of national football teams based on an integral assessment remains relevant.

The objective of the study is to determine the features of the competitive activities of national football teams based on the integral assessment of game tactics.

Materials and Methods

Participant

The study was conducted during the 2024 European Football Championship. The competitive activities of national football teams from European countries (Germany, Spain, England, Switzerland, France, Portugal, Netherlands, Turkey) were analyzed, focusing on the tactics of the game in 50 halves.

Study Organization

The following methods were used in the study: theoretical analysis of literature sources; pedagogical observation of competitive activities; analysis of video materials of competitive activities; methods of mathematical statistics.

Based on the theoretical analysis of literature sources, the research topic was identified, and the research hypothesis was developed.

The methods of pedagogical observation of competitive activities and analysis of video materials of competitive activities served as the basis for developing a methodology for determining the integral assessment of the tactics of national football teams.

The integral assessment of the tactics of a football team is based on the following points:

- The indicators of competitive activity must be recorded in two phases of the game – the ball possession phase and the ball picking phase;
- In the ball possession phase, quantitative and qualitative indicators of positional and fast attacks, as well as the number and quality of penetrating attacks, are evaluated;
- In the ball picking phase, quantitative and qualitative values of ball pickings and interceptions performed in three zones of the football field (first – low pressing, second – medium pressing, third – high pressing) are assessed;
- The integral assessment of the tactics of a football team consists of 10 specific coefficients. Five coefficients characterize the team's performance in the ball picking phase, and the other five in the ball possession phase;
- The value of each specific coefficient ranges from 0 to 1. That is, the value of the numerator is less than the value of the denominator.

The integral assessment of a football team's tactics is determined using the following formula (Kostiukevych, & Konnov, 2021; Kostykevich, et al., 2023):

$$IAtg = HPC + HPEF + LPEF + CBPE + BIEC + PAEC + SPAEC + GSS + CrC + CC \quad (1)$$

Coefficients in the ball pickup phase 1.

1. High pressing coefficient (HPC)

$$HPC = \frac{\sum_{1=1}^{n} TTA(t+i)3^{rd} - a\ zone}{\sum_{1=1}^{n} TTA(t+i)1 - a + 2^{nd} zones} \quad (2)$$

where: $\sum_{1=1}^{n} TTA(t+i)3^{rd} - a\ zone$ is the number of technical and tactical actions (tackles and interceptions) performed in certain areas of the field – 1st, 2nd, 3rd areas of the field.

2. High pressing efficiency factor (HPEF)

$$HPEF = \frac{\sum_{1=1}^{n} TTA(t+i) \div s\ in\ 3^{rd}\ zone}{\sum_{1=1}^{n} TTA(t+i) \div t\ in\ 3^{rd} zone} \quad (3)$$

where is stands for successful TTAs; and t – for total TTAs.

3. Low pressing efficiency factor (LPEF)

$$LPEF = \frac{\sum_{1=1}^{n} TTA(t+i) \div s\ in\ 1^{st}\ zone}{\sum_{1=1}^{n} TTA(t+i) \div t\ in\ 1^{st} zone} \quad (4)$$

where $\sum_{1=1}^{n} TTA(t+i)$: s – is the number of successful tackles and interceptions of the ball;

$\sum_{1=1}^{n} TTA(t+i) \div t\ in\ 1^{st} zone$ – is the total number of tackles and interceptions of the ball.

4. Coefficient of ball picking efficiency (CBPE)

$$CBPE = \frac{\sum_{1=1}^{n} TTA(t)s}{\sum_{1=1}^{n} TTA(t)t} \quad (5)$$

$\sum_{1=1}^{n} TTA(t)s$ where is the number of successful tackles during the game;

$\sum_{1=1}^{n} TTA(t)t$ is the total number of tackles during the game.

5. Ball interceptions efficiency coefficient during the game (BIEC)

$$BIEC = \frac{\sum_{1=1}^{n} TTA(i)s}{\sum_{1=1}^{n} TTA(i)t} \quad (6)$$

where $\sum_{1=1}^{n} TTA(i)s$ is the number of successful interceptions made during the game;

$\sum_{1=1}^{n} TTA(i)t$ is the total number of interceptions of the ball during the game.

Coefficients in the ball possession phase

1. Penetration attack effectiveness coefficient (PAEC)

$$PAEC = \frac{\sum_{1=1}^{n} PA(point\ s)}{\sum_{1=1}^{n} PA(point\ s) + 10} \quad (7)$$

where $\sum_{1=1}^{n} PA(point\ s)$ is the total amount of points when performing penetrating attacks (PA); 10-number value.

2. Successful penetration attack efficiency coefficient (SPAEC)

$$SPAEC = \frac{\sum_{1=1}^{n} SPA}{\sum_{1=1}^{n} (PA + SPA)} \quad (8)$$

where SPA means successful penetration attacks.

3. Goalscoring situation coefficient (GSS)

$$GSS = \frac{\sum_{1=1}^{n} GSO, point\ s}{\sum_{1=1}^{n} (PA + SPA), point\ s} \quad (9)$$

where $\sum_{1=1}^{n} GSO$ is the sum of points for creating goalscoring opportunities during the game;

$\sum_{1=1}^{n} (PA + SPA)$ is the sum of points for penetrating attacks and successful penetrating attacks during the game.

4. Creativity coefficient (CrC)

$$CrC = \frac{\sum_{1=1}^{n} (PA + SPA)}{\sum_{1=1}^{n} (PosA + FA)} \quad (10)$$

where $\sum_{1=1}^{n} (PA + SPA)$ is the number of penetrating attacks (PA) and successful penetrating attacks (SPA) conducted by the team during the game;

$\sum_{1=1}^{n} (PosA + FA)$ is the number of positional attacks (PosA) and fast attacks (FA) carried out by the team during the game.

5. Combinability coefficient (CC)

$$CC = \frac{\sum_{1=1}^{n} BP}{600} \quad (11)$$

where $\sum_{1=1}^{n} BP$ is the number of ball passes during the first half of the game; 600 is a numerical value

The specific coefficients for the tactics of a football team in the ball picking phase are determined based on the application of pressing in three zones of the field.

To determine the specific coefficients in the possession phase, it is necessary to consider: from the right flank; from the left flank; from the right half flank, from the left half flank; from the central part of the penalty area (Fig. 1).

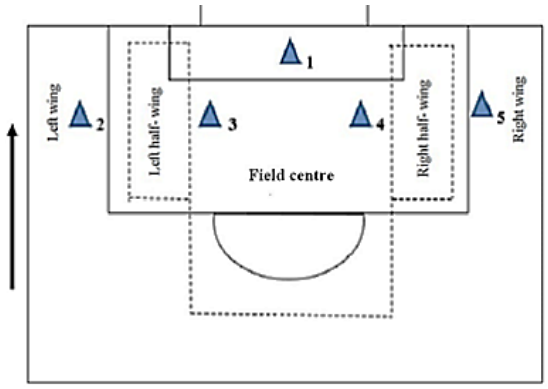


Fig. 1. Sharpening tactical moves during the penetrating attacks of a football team (Kostiukevych, et. al., 2023)

Penetrating attacks are divided into two types: penetrating attacks and successful penetrating attacks. Each successful penetrating attack ends with the awarding of a corner or free kick or a shot on goal.

Penetrating attacks are evaluated in points depending on their content (Table 1). In the development of the evaluation scale for penetrating attacks of a football team, the coordination complexity (CC) of the goalkeeper's play was taken into account. Technical-tactical actions performed by the goalkeeper using specific motor skills are classified as the 1st, 2nd, and 3rd levels of CC. The 4th level of CC includes the goalkeeper's "saves" when catching, deflecting, or intercepting the ball. The 5th level of CC includes the goalkeeper's "saves"that are performed based on high athletic skill combined with a sense of intuition (anticipation).

Table 1. Penetrating attack evaluation scale in football

Score, Points	The Nature of Penetration Attacks
1	Penetrating attack that ends in losing the ball
2	A game situation where there is an inaccurate shot on goal, or a free kick/corner kick is awarded to the attacking team
3	Penetrating attack that ends with an accurate shot on goal, but the goalkeeper controls the ball without high difficulty in coordination
4*	The game situation is characterized by a "goal-scoring opportunity," but ends with the loss of the ball
5*	A favorable game situation for a goal shot from outside the penalty area, but the shot is inaccurate
6*	A favorable game situation for a shot on goal inside the penalty area, but the shot is inaccurate
7*	An accurate shot on goal from outside the penalty area, with the goalkeeper making a save involving complex coordination
8*	An accurate shot on goal within the penalty area, with the goalkeeper making a save
9*	An accurate shot on goal within the penalty area, when the goalkeeper makes the most difficult saves combined with anticipation; a penalty kick is awarded
10*	Game situation ending with a goal

Notes: 4-10* – goalscoring situations

Based on Table 1, specific coefficients of the football team's tactics, such as PAEC, SPAEC, GSS, are determined.

GSS is determined by the ratio of the sum of points for goal-scoring opportunities to the sum of points for all penetrating attacks.

A goalscoring situation is considered when the position of the ball and the placement of the players from both teams are favorable for an accurate shot on goal (Fig. 2).

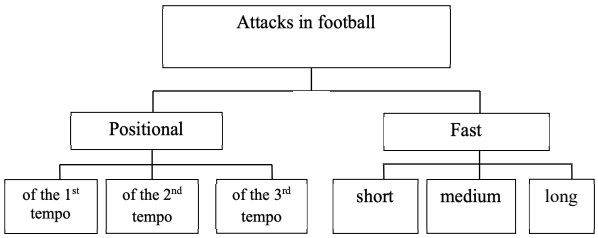


Fig. 2. Classification of attacks in football (according to Kostiukevych, et. al., 2023)

There are 1st, 2nd, and 3rd tempo positional attacks. A characteristic feature of the 1st tempo positional attack is that it is executed quickly with optimal use of the playing space. The duration of such attacks consists of 4-6 tactical moves. A 2nd tempo positional attack conditionally consists of two 1st tempo attacks (7-10 tactical moves). Long-term control of the ball (more than 10 tactical moves) characterizes the 3rd tempo positional attack.

Regarding quick attacks, they are defined by the transfer of the ball to the opponent's goal with the shortest duration and the smallest playing space. Short quick attacks start in the 3rd zone of the field, medium quick attacks begin in the 2nd zone, and long quick attacks start in the 1st zone.

The combination style of a football team's play is characterized by the coefficient of combination play CC, which is determined by the ratio of the number of ball passes in one half to a conditional number – 600.

The integral assessment is determined as the arithmetic mean of the two halves.

The control of the tactics of a football team's play is carried out based on a special protocol (Kostiukevych et. al., 2023).

Statistical Analysis

The statistical analysis of the research results was conducted using descriptive mathematical statistics. The sample was characterized by determining the arithmetic mean ($\bar{x}$), standard deviation (S), and coefficient of variation (V). The significance of differences in the indicators was assessed using the parametric Student's t-test for independent samples. Prior to this, the data's conformity to a normal distribution was verified using the Shapiro-Wilk W-test. The mathematical processing of the study results was performed using the Data Analysis package in MS Office Excel and the Statistica software. The statistical analysis of the research outcomes was carried out following the principles of descriptive statistics (Byshevets et al., 2019).

Results

During the final matches of the 2024 European Football Championship, the tactics of national football teams were recorded based on the above-described methodology. Based on the protocols of 50 halves of the teams' games, a ten-point scale was developed to assess the level of specific coefficients of the tactics of national football teams (Table 2).

The scale was designed with regard to the rule of three sigmas according to the algorithm presented below Kostiukevych et. al., 2023).

The first step is to determine of the mean value ($\bar{x}$).

The second step is to determine of the standard deviation (S).

The third step is to determine of the range (the difference between $\bar{x}$ +3S and $\bar{x}$ –3S).

The fourth step is to determine of the interval between points:

$$P = \frac{(\bar{x} + 3S) - (\bar{x} - 3S)}{9} \qquad (12)$$

where: 9 is the number that corresponds to the number of columns in the scale, where the 1st column is assigned the value (–3S).

The fifth step is the formation of a ten-point scale:

1 point – value ($\bar{x}$ –3S);

2 points – value ($\bar{x}$ –3S) plus the value of the interval between points, and so on.

The ten-point scale of the tactics of national football teams allows for the assessment of the level of manifestation of individual specific coefficients, as well as the overall IAtg. On the other hand, graphical models of the tactics of football teams are developed based on the ten-point scale.

Analysis of the tactics of both club and national football teams allows us to assert that during a match, teams change their tactical approaches to the game in the first and second halves (Kostiukevych et al., 2020). This is primarily due to the current score of the match or a change in tactics depending on the tactics of the opposing team. Based on this, during the European Championship, the tactics of the teams were analyzed both for entire matches and individual halves (Table 3).

From Table 3, it is evident that the highest values in the structure of the IAtp are held by specific coefficients such as PAEC (0.79 ± 0.16 points); BIEC (0.74 ± 0.18 points); LPEF (0.65 ± 0.10 points); and GSS (0.62 ± 0.12 points). At the same time, HPC, CrC , and CC are sufficiently informative for characterizing the tactics of a football team. HPC reflects the team's application of high pressing, that is, ball picking and interceptions in the 3rd zone of the field. Based on the values of CrC, it is possible to determine the focus of the team's attacking actions, aiming to turn most attacks into penetrating attacks, the realization of which leads to scoring goals.

The statistical data presented in Table 4 can be considered as model benchmarks for high-level club and national teams.

One of the tasks of this study was to determine the components of the game tactics of national teams at the quarter-final, semi-final, and final stages. Table 4 presents the values of specific game tactics coefficients for the national teams in the quarter-finals of the European Championship. Practically, these are the strongest European teams, except for Belgium, Italy, and Croatia, which have high FIFA rankings but did not make it to the quarter-finals. Based on the rankings of the top three teams in the quarter-finals – Portugal (IAtg – 5.93 points) and France (IAtg – 5.63 points),

Table 2. Ten-point scale of specific performance indicators for competitive activities of national football teams

Specific Indicators	Level of Specific Performance Indicators for Competitive Activities, Points									
	Low		Below Average		Average		Above Average		High	
	1	2	3	4	5	6	7	8	9	10
HPC	0.08	0.12	0.16	0.20	0.24	0.28	0.32	0.36	0.40	0.44
HPEF	0.24	0.30	0.36	0.44	0.52	0.60	0.68	0.76	0.84	0.92
LPEF	0.35	0.42	0.49	0.56	0.63	0.70	0.77	0.84	0.91	0.98
CBPE	0.23	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68
BIEC	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
PAEC	0.61	0.65	0.69	0.73	0.77	0.73	0.77	0.81	0.85	0.89
SPAEC	0.28	0.33	0.38	0.43	0.48	0.53	0.58	0.63	0.68	0.73
GSS	0.26	0.34	0.42	0.50	0.58	0.66	0.74	0.82	0.90	0.98
CrC	0.12	0.19	0.26	0.33	0.40	0.47	0.54	0.61	0.68	0.75
CC	0.29	0.33	0.37	0.41	0.45	0.49	0.53	0.57	0.61	0.65
IAtg	4.33	4.62	4.91	5.20	5.49	5.78	6.07	6.36	6.65	6.94

Table 3. Indicators of game tactics (in one half) of national teams at the 2024 European Football Championship (n = 50)

Specific indicators	Statistical indicators, points				
	$\bar{x}$	S	x_{max}	x_{min}	V, %
IAtg	5.62	0.43	6.73	4.78	7.7
HPC	0.26	0.06	0.38	0.10	23.9
HPEF	0.58	0.08	0.73	0.36	14.2
LPEF	0.65	0.10	0.82	0.35	16.1
CBPE	0.47	0.08	0.61	0.25	17.0
BIEC	0.74	0.08	0.86	0.41	10.8
PAEC	0.79	0.16	0.85	0.54	7.6
SPAEC	0.49	0.07	0.63	0.32	14.1
GSS	0.62	0.12	0.76	0.23	18.9
CrC	0.42	0.10	0.69	0.24	23.8
CC	0.47	0.06	0.63	0.34	13.7

the playing potential of these teams in upcoming high-level international competitions can be assessed. It is worth noting that neither of these teams made it to the final of the 2024 European Championship.

The average IAtg value of the national teams in the quarter-finals of the European Football Championship is 5.51 ± 0.24 points, which is the same as the average IAtg value of the teams in the quarter-finals (Table 5). This may indicate a stable level of competitive activity among the leading national teams of European countries.

It should be noted that in the semi-final matches, high pressing was used more frequently compared to the quarter-final matches, as indicated by the increase in HPC from 0.22 ± 0.08 to 0.28 ± 0.06 (21.4 %). This means that the teams participating in the semi-final matches used a more aggressive method of playing.

Choosing an active method of play, i.e., building the game based on playmaking tactics, allowed the national team of Spain to win the final match and become the champion of the 2024 European Football Championship. The IAtg of the

Table 4. Indicators of game tactics of national teams in the quarter-finals of the European Football Championship

Matches	Score *	Specific coefficients, points										IAtg	Ranking
		HPC	HPEF	LPEF	CBPE	BIEC	PAEC	SPAEC	GSS	CrC	CC		
Germany	1	0.20	0.67	0.71	0.41	0.84	0.83	0.46	0.67	0.49	0.47	5.75	2
Spain	2	0.24	0.36	0.72	0.59	0.74	0.83	0.54	0.66	0.29	0.47	5.44	5.5
England	1	0.32	0.50	0.62	0.47	0.69	0.79	0.28	0.45	0.48	0.52	5.12	8
Switzerland	1	0.23	0.36	0.72	0.38	0.74	0.81	0.37	0.77	0.39	0.45	5.22	7
France	0	0.31	0.59	0.69	0.49	0.77	0.81	0.41	0.65	0.45	0.46	5.63	3
Portugal	0	0.33	0.71	0.74	0.56	0.78	0.81	0.44	0.42	0.58	0.56	5.93	1
Netherlands	1	0.19	0.53	0.81	0.39	0.69	0.83	0.38	0.78	0.36	0.48	5.44	5.5
Turkey	0	0.11	0.77	0.73	0.34	0.56	0.84	0.59	0.75	0.43	0.45	5.52	4
$\bar{x}$		0.22	0.56	0.72	0.45	0.73	0.82	0.49	0.64	0.43	0.48	5.51	
S		0.08	0.14	0.07	0.09	0.09	0.02	0.11	0.12	0.10	0.04	0.28	
V, %		35.1	25.7	9.3	19.5	13.5	2.1	22.2	19.2	23.7	8.0	5.2	

Notes: * – score of regular game time.

Table 5. Indicators of game tactics of national teams in the semi-finals of the 2024 European Football Championship

Matches	Score *	Specific coefficients, points										IAtg
		HPC	HPEF	LPEF	CBPE	BIEC	PAEC	SPAEC	GSS	CrC	CC	
England	2	0.35	0.51	0.69	0.42	0.78	0.82	0.39	0.74	0.39	0.59	5.68
Netherlands	1	0.24	0.67	0.69	0.45	0.77	0.79	0.50	0.78	0.30	0.39	5.58
Spain	2	0.22	0.65	0.70	0.49	0.81	0.76	0.46	0.62	0.30	0.57	5.58
France	1	0.30	0.37	0.69	0.46	0.69	0.68	0.55	0.44	0.57	0.44	5.19
$\bar{x}$		0.28	0.55	0.69	0.46	0.76	0.76	0.48	0.65	0.39	0.49	5.51
S		0.06	0.14	0.01	0.03	0.06	0.07	0.04	0.17	0.13	0.09	0.24
V, %		22.8	24.9	0.7	7.4	7.8	9.1	9.2	25.7	34.1	20.1	4.4

Notes: * – score of regular game time

Table 6. Indicators of game tactics of national teams in the final match of the 2024 European Football Championship

Matches	Half Time	Score*	Specific coefficients, points										IAtg
			HPC	HPEF	LPEF	CBPE	BIEC	PAEC	SPAEC	GSS	CrC	CC	
Spain	1	0	0.24	0.50	0.71	0.30	0.88	0.82	0.32	0.71	0.46	0.46	5.40
England		0	0.21	0.56	0.89	0.50	0.80	0.74	0.50	0.72	0.21	0.38	5.51
Spain	2	2	0.29	0.74	0.67	0.41	0.87	0.89	0.70	0.86	0.48	0.48	6.39
England		1	0.17	0.33	0.56	0.47	0.65	0.85	0.27	0.87	0.41	0.34	4.92
Average game data													
Spain	-	2	0.27	0.45	0.69	0.36	0.88	0.86	0.51	0.79	0.47	0.47	5.75
England	-	1	0.19	0.45	0.73	0.49	0.73	0.80	0.39	0.79	0.31	0.39	5.27
Difference, %			+29.6	0	-5.5	-26.5	+17.0	+6.9	+23.5	0	+34.0	+17.0	+8.3

Notes: * – score of regular game time

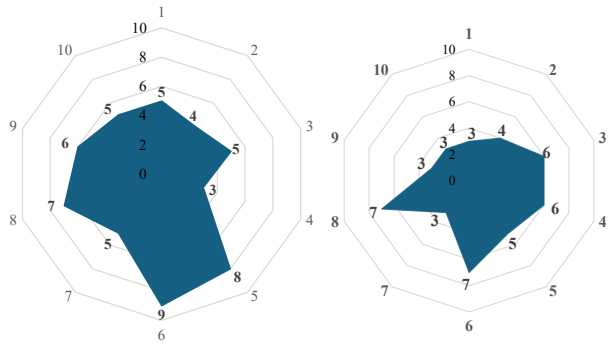
Spanish national team was 5.75 points, which is 0.48 points (8.3 %) higher than that of the England national team (Table 6).

When considering the values of individual specific game tactics coefficients of the national teams in the final match of the 2024 European Football Championship, the most significant difference in favor of the Spanish team is observed in the values of HPC – 0.08 points (29.6 %), SPAEC – 0.12 points (23.5 %), CrC – 0.16 points (34.0 %), and CC – 0.08 points (17.0 %).

The game tactics of the Spanish national team throughout the tournament, including the final match, were based on active use of high pressing, a high level of execution of penetrating attacks, and the creative and combinatorial play.

A example of the tactical advantage of the Spanish national team's game model over the English national team's game model in the final match of the 2024 European Football Championship can be illustrated by Figure 3.

Therefore, the presented research results on the issue of control and analysis of the game tactics of national football teams are relevant to the needs of the theory and practice of high-performance sports.



(a) (b)

Fig. 3. Models of game tactics in the final match of the 2024 European Football Championship of the national teams of Spain (a) and England (b). Notes: 1 – HPC; 2 – HPEF; 3 – LPEF; 4 – CBPE; 5 – BIEC; 6 – PAEC; 7 – SPAEC; 8 – GSS; 9 – CrC; 10 – CC

Discussion

Discussion questions related to any research are primarily determined by the relevance of the problem, scientific inquiry, and the interpretation of research results concerning the identified problem.

The chosen topic of scientific inquiry is undoubtedly relevant to the development of team sports at the present stage, as confirmed by previous studies by domestic (Kostiukevych et al., 2019; Bezmylov et al., 2020; Mitova & Shynkaruk, 2022) and foreign scientists (Sarmento et al., 2014; Aguinj et al., 2020; Simons, 2019).

This research complements the theoretical foundations of monitoring competitive activities of athletes in team sports (Doroshenko, et al., 2019; Mitova, et al., 2023), particularly regarding the analysis of competitive activities in these sports

based on the integral assessment of competitive activities (Shynkaruk et al., 2020; Konnov, 2021; Kostiukevych et al., 2022).

The developed methodology for monitoring and analyzing the tactics of national football teams allows for increased efficiency in managing players' competitive activities both within the framework of the respective tournament and directly in the match. This is crucial for the operational correction of footballers' competitive activities (Perepelytsia, 2021; Kostiukevych, et al., 2023).

The structure of the integral assessment of a football team's game tactics consists of various components that characterize the technical and tactical activities of the team in the phases of possession and picking. Comparing specific indicators of a football team's game tactics over a given preparation period allows for adjustments in management interventions in the training and competitive processes of high-level footballers.

As for the interpretation of the research results, they are presented in the article according to the research objective using a specific algorithm: developing the research methodology – conducting the research – analyzing the research results.

It should be noted that an important component of the interpretation of the research results is the development of a ten-point scale for assessing the level of game tactics of national football teams. Based on this scale, the level of manifestation of individual tactical components of the team's game is determined, and graphic models of the game are formed.

Overall, the conducted research provided new knowledge regarding the management of the competitive process of national football teams.

Conclusions

Modern trends in football development require new methodological approaches to control and analyze the competitive activities of high-level club and national football teams. One such approach is the integral assessment of the team's competitive activities, taking into account the main aspects of game tactics.

The peculiarities of the competitive activity of the national teams are determined by the interaction of the players during defensive and offensive actions. The criteria for such interactions are specific indicators of the integral assessment of team game tactics. The average values of these indicators in one half are (in points): ball pickup phase – 0.26 ± 0.06 (HPC), 0.58 ± 0.08 (HPEF), 0.65 ± 0.10 (LPEF), 0.47 ± 0.08 (CBPE), 0.74 ± 0.08 (BIEC); ball possession phase – 0.79 ± 0.16 (PAEC), 0.49 ± 0.07 (SPAEC), 0.62 ± 0.12 (GSS), 0.42 ± 0.10 (CrC), 0.47 ± 0.06 (CC). The integral assessment of the teams' game tactics corresponds to a value of 5.62 ± 0.43 points.

A ten-point scale for assessing the level of game tactics of national football teams has been developed, based on which a targeted analysis of the manifestation of tactical components of the game in the phases of ball picking and possession is carried out.

The prospect of further research on the chosen problem will be determined by the search for ways to comprehensively control the competitive activities of club and national football teams based on integral and expert assessments.

Conventional abbreviations

HPC – high pressing coefficient;
HPEF – high pressing efficiency factor;
LPEF – low pressing efficiency factor;
CBPE – coefficient of ball picking efficiency;
BIEC – ball interceptions efficiency coefficient during the game;
PAEC – penetration attack effectiveness coefficient;
SPAEC – successful penetration attack efficiency coefficient;
GSS – goalscoring situation coefficient;
CrC – creativity coefficient;
CC – combinability coefficient;
IAtg – integral assessment of game tactics

Conflict of interests

The authors state that there is no conflict of interests.

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Інтегральна оцінка тактики гри національних збірних футбольних команд

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 6 табл., 3 рис., 32 джерела.

Мета – визначити особливості змагальної діяльності національних збірних футбольних команд на основі інтегральної оцінки тактики гри.

Матеріал і методи. Дослідження було проведено під час Чемпіонату Європи з футболу 2024 року. Змагальна діяльність національних футбольних команд європейських країн (Німеччина, Іспанія, Англія, Швейцарія, Франція, Португалія, Нідерланди, Туреччина) була проаналізована з акцентом на тактику гри у 50 таймах. Методи: теоретичний аналіз літературних джерел; педагогічне спостереження за змагальною діяльністю; аналіз відеоматеріалів змагальної діяльності; методи математичної статистики. Статистичний аналіз результатів дослідження був проведений за допомогою описової математичної статистики. Характеристики вибірки визначалися за допомогою обчислення середнього арифметичного ($\bar{x}$), стандартного відхилення (S) та коефіцієнта варіації (V). Значущість відмінностей у показниках оцінювалася за допомогою параметричного t-критерію Стьюдента для незалежних вибірок. Перед цим відповідність даних нормальному розподілу перевірялася за допомогою тесту Шапіро-Уілка.

Результати. Розроблено методику інтегральної оцінки тактики національних футбольних команд. Інтегральна оцінка тактики команди складається з 10 специфічних коефіцієнтів, які відображають основні компоненти змагальної діяльності футболістів у фазах володіння м'ячем та відбору м'яча. Було проаналізовано змагальну діяльність у 50 таймах Чемпіонату Європи з футболу 2024 року. Середнє значення інтегральної оцінки тактики національних футбольних команд становило 5,62 ± 0,43 бала. Результати показали значні тактичні відмінності між командами, причому використання Іспанією високого пресингу та креативної гри сприяло їхній перемозі в чемпіонаті. Було розроблено десятибальну шкалу для оцінки тактики національних футбольних команд, на основі якої інтерпретується рівень змагальної діяльності.

Висновок. Розроблена методика моніторингу та аналізу тактики гри футбольних команд дозволяє цілеспрямовано здійснювати управлінські впливи на змагальну діяльність футболістів на оперативному, поточному та етапному рівнях.

Ключові слова: футбол, національні команди, змагальна діяльність, тактика гри, інтегральна оцінка, методика, шкала, моніторинг.

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Cite this article as: Kostiukevych, V., Shynkaruk, O., Borysova, O., Voronova, V., Vozniuk, T., Doroshenko, E., Sushko, R., & Kulchytska, I. (2024). The Integral Assessment of Playing Tactics in National Football Teams. *Physical Education Theory and Methodology, 24*(5), 749-757. https://doi.org/10.17309/tmfv.2024.5.10

Received: 21.08.2024. Accepted: 19.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Revealing the Peculiarities of Female Students' Physiological Characteristics with Different Somatotypes in the Absence of Compulsory Physical Activity at University

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Accepted for Publication: September 19, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.11

Abstract

Objectives. The purpose of the study was to determine the parameters of female students' physiological characteristics with different somatotypes, which they achieved by exercising outside the university due to COVID-19 quarantine and air raids during the hostilities in Ukraine.

Material and methods. The study involved 66 female students aged 17.8 ± 0.6 years, who belonged to different somatotypes and had no reservations about engaging in different amounts of physical activity. The Shtefko-Ostrovsky method, modified by S. Darskaja, was used to diagnose the somatotype. The necessary empirical data were obtained through the performing well-known functional tests that allowed to determine blood pressure, heart rate in different situations, vital capacity, vital capacity index, maximum isometric strength index, and Robinson index. The parameters of these characteristics were determined in female students with each of the four available somatotypes during the study, and each parameter was compared with different somatotypes. The testing was conducted at the beginning (January) and at the end (May-June) of the academic semester, but during one academic year.

Results. At the beginning, and even more so at the end of the academic year, the parameters of the studied characteristics in female students with each of the available somatotypes differed from each other (p-values ranging at the level from 0.05 to 0.000). The volumes and conditions of physical activity used during the academic year did not lead to significant changes in the physiological characteristics of all female students, i.e. parameters remained at the previously achieved level. At the same time, the presence of peculiarities caused by the girl's belonging to a certain somatotype was observed.

Conclusions. Identifying the peculiarities in changes of female students' physiological characteristics' parameters, taking into account their somatotypes, is a perspective and significant direction for modernization of physical education at university. The obtained data will contribute to the individualization of the content and normative bases of physical education for female students, using information on the manifestation and change of parameters of various characteristics, including physiological ones.

Keywords: physiological characteristics, female students, differentiation, physical education, physical activity, COVID-19.

Introduction

In recent years, increased attention has been paid to students' physical activity in extracurricular time (American College, 2017; Banakh, 2019; Get Active, 2020; Global action plan on physical activity 2018-2030). Some of the main reasons are as follows: this physical activity is considered as one of the most effective forms in the successful solution of university physical education tasks (Zhang & Wu, 2020; Abrantes et al., 2022; Wilmore et al., 2022); the number of physical education classes implemented during the week and academic year at universities does not provide the specified number of physical education classes (Piestrzyński et al.,

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2021; López-Valenciano et al., 2021; James et al., 2023); analysis of curricula for bachelor's and master's degrees shows a tendency to further reduce the number of physical education classes (Institute of Medicine, 2013; Wiium, Säfvenbom, 2019; Annear et al., 2022).

At the same time, we have recently noted a further increase in researchers' attention to the problem of modernizing university physical education (Vaquero-Solís et al., 2020; Kljajević et al., 2021; Annear, 2022; Ge et al., 2024). Some of the main reasons for the need to modernize this pedagogical process are largely due to: quarantine during the COVID-19 epidemic, air raids as a result of hostilities, the orientation of the educational process at the university towards the optional nature of physical education, and some other problems of students' physical activity (Romero-Blanco, et al, 2020; Wilson et al., 2021; Misharskyi et al., 2023).

Due to this situation, the problem of individualization and personalization of physical education is particularly relevant, which involves providing students with appropriate counseling services, orientating them to independent physical activity in non-classroom time, and offering each individual the optimal parameters of physical activity (Coulter et al., 2016; Banakh & Iedynak, 2021; Frąckiewicz, 2023). In other words, we are talking about designing an educational route for each student that helps him or her to solve the task (Wiium, Säfvenbom, 2019). The practical implementation of this personalization in physical education, including at university, involves the use of a predictive and effective marker, one of which is the somatotype (Cinarli & Kafkas, 2019; Campa et al., 2020; Iedynak et al., 2021). Knowledge about the peculiarities of physiological characteristics is also important, as they are one of the leading factors in determining the content of the physical activity program for each student (Katzmarzyk & Silva, 2013; Wilmore et al., 2022).

Given the above, it was found that such information is insufficient, and this does not contribute to solving the identified scientific problem. There is no data on the peculiarities of manifestation and changes in the parameters of physiological characteristics of girls with different somatotypes in the absence of compulsory physical activity during their studies at university. Such information is important because it will contribute to the formation of individual programs to successfully solve the problem of improving the physiological characteristics of girls with different somatotypes (Stewart et al., 2014; Iedynak et al., 2017). The importance of achieving this result is due to several reasons, one of which is that the parameters of girls' physiological characteristics are lower than necessary. This, in turn, does not contribute to the quality of girls' educational activities, professional duties in the future, various types of household activities, maintaining and improving their health, physiological capacities, and other important characteristics for ensuring a high quality of life (Campa, Greco, 2022). Thus, given the above information, there is a need to conduct research in this area.

Materials and methods

Study participants

The study involved 66 girls, each aged 17.8 ± 0.6 years. They belonged to different somatotypes and had no reservations about the use of different amounts of physical activity. The Shtefko-Ostrovsky method in the modification of S. Darskaja was used to diagnose the somatotype. Thus, 12 belonged to the asthenic somatotype (A-type), 22 – thoracic somatotype (T-type), 22 – muscular (M-type), and 10 – digestive (D-type).

Study organization

Somatotypes were diagnosed at the beginning of the experiment. The use of this particular scheme was due to the following reasons: the main characteristics of the scheme are very similar to the Heath-Carter scheme, which is most often used by researchers from Europe and the United States (Carter & Heath,1990; Stewart et al., 2014; Bertuccioli et al., 2022). The selection of the Shtefko-Ostrovsky scheme makes it extremely possible to establish a certain trend, especially manifestations and changes in physical readiness in comparison with the data of other researchers (Sands, 2012; Iedynak et al., 2021).

The study was based on characteristics that reflected the state of functioning of girls' respiratory, cardiovascular, and neuromuscular systems. At the beginning and end of the study, the parameters of these characteristics were determined in girls with each of the four available somatotypes. In addition, a comparative analysis of the parameters of each characteristic that marked the existing somatotypes was carried out. Each functional test used is well-known, widely used in practice, and recommended by researchers as reliable and informative (American College of Sport Medicine, 2017; Wilmore et al., 2022).

These tests were used to determine vital capacity (VC); heart rate (HR) in different situations (at rest, after using a dosed load, during recovery from the used load); blood pressure (systolic – SBP, diastolic – DBP); vital capacity index (VCI = VC/body mass), maximum isometric strength index (IMIS = maximum isometric strength/body mass); Robinson index (RI = (SBP × HR)/100). All the specified requirements were met during the application of these tests. The data obtained were interpreted as follows: HR reflected the state of functioning of the heart, and together with blood pressure and RI – the state of the cardiovascular system at rest; the value of VC indicated the ability of the lungs to receive oxygen, the value of VCI – the state of the respiratory system in terms of a full supply of oxygen to the body. The value of IMIS allowed to establish the state of development of the skeletal muscles of girls. This indirectly indicates the state of excessive accumulation in the muscles of structural and energy potentials that increase their working capacity. We used certified equipment: to determine the blood pressure – BP AG1-30 Microlife, to determine the IMIS – handgrip Camry dynamometer, to determine the VC and VCI – Cardio-Spiro, NDD EasyOne Plus System 2000-2 spirometer. VCI and IMIS included the determination of body mass, for this purpose, OMRON BF 511 scales were used. Testing was conducted at the beginning (January) and end (May-June) of the academic semester during one academic year. The results were compared with each other first in each somatotype, then in different somatotypes. The increase, or decrease in the parameters of a certain characteristic or its manifestation at the previously achieved level was determined.

The study was planned and implemented by the principles of bioethics set out by the World Medical Association (WMA-2013) in the Declaration of Helsinki on Ethical Principles for Medical Research Involving Human

Subjects and by UNESCO in the Universal Declaration on Bioethics and Human Rights. This helped to fulfill the requirements of voluntariness, anonymity, and trust; all girls provided informed written consent to participate in the study. The study protocol was approved by the Ethical Committee of Kremenets Regional Humanitarian Pedagogical Academy named after Taras Shevchenko.

Statistical Analysis

All statistical analyses were performed using SPSS Version 21. For each assessment, the following calculations were performed: arithmetic mean (M), standard deviation (SD), and Kolmogorov-Smirnov Test (KS). The latter allowed us to establish the nature of the distribution of individual values in each sample of girls. Based on the results of this analysis, when comparing two means, the Student's T test for related and unrelated samples or nonparametric methods were used; the 0.05, 0.01, and 0.001 probability levels were used to indicate statistical significance (Robinson, 2016; Weir & Vincent, 2020).

Results

Before studying the empirical data, we analyzed them from the point of view of compliance with the normal distribution of values of each physiological characteristic in

Table 1. Results of girls with different somatotypes at the beginning of the study

N	The name of the parameter	On beginning				
		M_1	SD	Min	Max	K-S, p
	A-type (n = 12)					
1	VC, ml	2380.00	274.84	2110.00	3070.00	<0.10
2	HR at rest, bpm^{-1}	79.20	3.30	72.00	81.00	>0.20
3	HR after exercise, bpm^{-1}	119.50	6.50	110.00	130.00	>0.20
4	SBP, mmHg	112.83	8.83	102.00	130.00	>0.20
5	DBP, mmHg	66.75	4.33	60.00	72.00	>0.20
6	Recovery time after exercise, s	148.42	14.48	116.00	165.00	>0.20
7	VCI, $ml \cdot kg^{-1}$	44.83	3.83	41.00	53.00	>0.20
8	IMIS, %	45.08	4.76	38.00	52.00	>0.20
9	RI, conditional units	97.17	5.01	87.00	104.00	>0.20
	T-type (n = 22)					
1	VC, ml	2750.00	277.85	2350.00	3480.00	<0.20
2	HR at rest, bpm^{-1}	76.50	3.73	72.00	84.00	>0.20
3	HR after exercise, bpm^{-1}	112.50	7.18	103.00	126.00	>0.20
4	SBP, mmHg	117.91	5.11	108.00	126.00	>0.20
5	DBP, mmHg	72.09	3.44	68.00	81.00	<0.15
6	Recovery time after exercise, s	150.73	10.11	126.00	168.00	>0.20
7	VCI, $ml \cdot kg^{-1}$	44.18	4.72	33.00	51.00	<0.20
8	IMIS, %	47.18	3.47	41.00	54.00	>0.20
9	RI, conditional units	93.41	5.00	84.00	102.00	>0.20
	M-type (n = 22)					
1	VC, ml	2490.00	223.61	2150.00	2900.00	>0.20
2	HR at rest, bpm^{-1}	74.63	2.97	68.00	78.00	>0.10
3	HR after exercise, bpm^{-1}	110.41	7.69	100.00	132.00	>0.20
4	SBP, mmHg	117.91	4.80	110.00	126.00	>0.20
5	DBP, mmHg	74.09	2.88	68.00	78.00	>0.20
6	Recovery time after exercise, s	150.09	11.33	119.00	163.00	<0.10
7	VCI, $ml \cdot kg^{-1}$	43.09	3.49	38.00	51.00	>0.20
8	IMIS, %	47.09	5.68	40.00	62.00	<0.20
9	RI, conditional units	89.82	7.10	71.00	103.00	>0.20
	D-type (n = 10)					
1	VC, ml	2550.00	259.14	2230.00	3100.00	>0.20
2	HR at rest, bpm^{-1}	75.80	2.53	73.00	81.00	>0.20
3	HR after exercise, bpm^{-1}	128.70	12.79	116.00	150.00	>0.20
4	SBP, mmHg	119.10	6.12	112.00	134.00	>0.20
5	DBP, mmHg	78.10	2.92	74.00	82.00	>0.20
6	Recovery time after exercise, s	164.30	24.65	126.00	198.00	>0.20
7	VCI, $ml \cdot kg^{-1}$	37.10	5.30	31.00	46.00	>0.20
8	IMIS, %	40.10	3.87	36.00	50.00	>0.20
9	RI, conditional units	89.60	4.17	84.00	97.00	>0.20

Note: a reliably significant difference between the two means is highlighted in color

the studied samples. The K-S Test was used, and the results in all cases revealed a normal distribution of values (Table 1).

When comparing the parameters of girls with the available somatotypes, differences between them were found. The largest number was found in girls with T-type, namely, in 6 of all 9 characteristics, the values differed by a statistically significant amount (Table 2).

This concerned a pair of samples T-type and A-type, as well as a pair of samples T-type and D-type. Specifying the identified differences, we note that in the first pair, all parameters were better in representatives of T-type, in the second pair – HR after exercise, recovery time after exercise, VCI, and IMIS, while DBR and RI parameters were better in girls with D-type.

At the same time, in the next pair of samples, it was found that D-type girls had higher DBR than M-type girls, while the latter had higher HR after exercise, recovery time after exercise, VCI, and IMIS. The revealed peculiarity of girls with M-type was the same as that of girls with T-type. This led to the detection of almost identical parameters in the studied characteristics in these samples, except VC, which was better in T-type, and DBR, which was higher in M-type.

Comparing the parameters of physiological characteristics of girls with A-type and D-type, which are extreme variants of body composition components development, the following was found. The former were marked by a better reaction of the cardiovascular system to dosed physical activity because their HR after exercise was 119.5 ± 6.5 bpm^{-1}, whereas in girls with D-type it was 128.7 ± 12.79 bpm^{-1} ($t = 3.725$; $p < 0.001$), as well as VCI (44.83 ± 3.83 and 37.1 ± 5.3 $ml \cdot kg^{-1}$, respectively; $t = 3.967$; $p < 0.001$), IMIS (45.08 ± 4.76 and 40.1 ± 3.87 %; $t = 2.657$; $p < 0.015$).

The repeated study, which took place at the end of the academic year, revealed certain features of changes in the parameters of the studied characteristics. One is the improvement in each somatotype of only certain characteristics, except A-type representatives. They did not have statistically significant changes in any indicator (Table 3).

There was only a certain tendency in their change, the most expressive positive – in VC, recovery time after exercise, VCI, negative – IMIS, RI.

In girls with T-type, the change was found in parameters 2 out of all 9 studied characteristics, in girls with M- and D-types – 1. At that, in T-type parameters IMIS deteriorated by 3.77 $ml \cdot kg^{-1}$ ($t = 2.939$; $p < 0.005$), VCI – by 2.59 % ($t = 2.160$; $p < 0.037$). The first of these indicators reflected the state of development of the neuromuscular system, namely the state of excessive accumulation in the muscles of structural and energy potentials that increase their working capacity. VCI showed the state of oxygen supply to the body.

Table 2. Differences in results of girls with different somatotypes at the beginning of the study

Result (points)	The name of the parameter								
	1	2	3	4	5	6	7	8	9
A - T									
t	-3.725	2.073	2.806	-2.134	-3.951	-0.546	0.410	-1.476	2.093
F	1.022	1.276	1.218	2.989	1.589	2.050	1.514	1.876	1.002
p	0.000	0.046	0.009	0.041	0.000	0.589	0.685	0.150	0.044
A - M									
t	-1.264	4.091	3.469	-2.185	-5.936	-0.373	1.344	-1.040	3.170
F	1.511	1.234	1.398	3.384	2.265	1.634	1.206	1.426	2.013
p	0.215	0.000	0.002	0.036	0.000	0.712	0.188	0.306	0.003
A - D									
t	-1.482	2.641	-2.183	-1.894	-7.045	-1.881	3.967	2.657	3.802
F	1.120	1.700	3.870	2.080	2.190	2.900	1.910	1.510	1.440
p	0.154	0.016	0.041	0.073	0.000	0.075	0.000	0.015	0.001
T - M									
t	3.419	1.835	0.933	0.000	-2.094	0.197	0.872	0.064	1.939
F	1.544	1.575	1.148	1.132	1.426	1.255	1.827	2.676	2.016
p	0.001	0.074	0.356	1.000	0.042	0.845	0.388	0.949	0.059
T - D									
t	1.925	0.538	-4.604	-0.575	-4.789	-2.234	3.790	5.162	2.095
F	1.150	2.170	3.180	1.430	1.380	5.940	1.260	1.240	1.440
p	0.064	0.595	0.000	0.570	0.000	0.033	0.001	0.000	0.045
M - D									
t	-0.670	-1.073	-5.043	-0.597	-3.636	-2.259	3.815	3.522	0.090
F	1.343	1.377	2.767	1.625	1.032	4.733	2.307	2.153	2.903
p	0.508	0.292	0.000	0.555	0.001	0.031	0.001	0.001	0.929

Table 3. Results of girls with different somatotypes at the end of the study and the statistical reliability of their change

N	The name of the parameter	At the end				$(M_1 - M_2)$	
		M_2	SD	Min	Max	t	p
	A-type (n = 12)						
1	VC, ml	2410.00	334.72	2010.00	3200.00	-0.240	0.813
2	HR at rest, bpm^{-1}	79.00	4.29	69.00	84.00	0.107	0.916
3	HR after exercise, bpm^{-1}	118.08	8.59	105.00	136.00	0.456	0.653
4	SBP, mmHg	112.58	6.79	104.00	127.00	0.078	0.939
5	DBP, mmHg	67.67	3.42	62.00	72.00	-0.576	0.571
6	Recovery time after exercise, s	145.58	15.58	112.00	163.00	0.461	0.649
7	VCI, $ml \cdot kg^{-1}$	45.33	5.25	40.00	56.00	-0.267	0.792
8	IMIS, %	44.58	5.38	39.00	54.00	0.241	0.812
9	RI, conditional units	97.67	6.61	85.00	105.00	-0.209	0.836
	T-type (n = 22)						
1	VC, ml	2710.00	277.25	2310.00	3440.0	0.478	0.636
2	HR at rest, bpm^{-1}	75.82	3.98	71.00	84.0	0.586	0.561
3	HR after exercise, bpm^{-1}	114.09	6.98	105.00	126.0	-0.746	0.460
4	SBP, mmHg	117.09	5.33	106.00	124.0	0.520	0.606
5	DBP, mmHg	72.59	3.89	68.00	84.0	-0.452	0.654
6	Recovery time after exercise, s	146.50	10.57	118.00	164.0	1.355	0.183
7	VCI, $ml \cdot kg^{-1}$	40.41	3.78	33.00	52.0	2.929	**0.005**
8	IMIS, %	44.59	4.43	38.00	56.0	2.160	**0.037**
9	RI, conditional units	92.59	6.34	83.00	105.0	0.475	0.637
	M-type (n = 22)						
1	VC, ml	2502.96	262.09	2150.00	3200.00	-0.176	0.860
2	HR at rest, bpm^{-1}	75.09	4.14	68.00	84.00	-0.419	0.678
3	HR after exercise, bpm^{-1}	108.91	7.33	96.00	126.00	0.662	0.512
4	SBP, mmHg	118.23	4.14	110.00	126.00	-0.236	0.815
5	DBP, mmHg	75.09	3.42	68.00	80.00	-1.049	0.300
6	Recovery time after exercise, s	143.09	11.98	110.00	156.00	1.992	0.053
7	VCI, $ml \cdot kg^{-1}$	46.32	5.05	41.00	59.00	-2.467	**0.018**
8	IMIS, %	49.18	7.84	42.00	68.00	-1.013	0.317
9	RI, conditional units	88.91	8.41	69.00	109.00	0.388	0.700
	D-type (n = 10)						
1	VC, ml	2600.00	273.74	2090.00	3000.00	-0.420	0.680
2	HR at rest, bpm^{-1}	76.20	3.19	72.00	82.00	-0.311	0.760
3	HR after exercise, bpm^{-1}	130.40	9.43	114.00	143.00	-0.338	0.739
4	SBP, mmHg	120.80	6.27	114.00	134.00	-0.614	0.547
5	DBP, mmHg	81.10	2.23	78.00	84.00	-2.579	**0.019**
6	Recovery time after exercise, s	161.40	17.05	124.00	180.00	0.306	0.763
7	VCI, $ml \cdot kg^{-1}$	38.50	2.99	33.00	44.00	-0.727	0.476
8	IMIS, %	42.50	3.60	36.00	50.00	-1.436	0.168
9	RI, conditional units	91.70	5.56	84.00	99.00	-0.956	0.352

Note: a reliably significant difference between the two means is highlighted in color

In girls with M-type, there was an improvement in VCI parameters, which amounted to an average of 3.23 $ml \cdot kg^{-1}$ ($t = -2.467$; $p < 0.018$).

In girls with D-type, an increase in DBR to 81.1 mmHg was detected, but, at the beginning of the study, these parameters were within the age-related norm. Therefore, this result was not considered an option for improving the indicator.

These changes contributed to increased differences between the parameters achieved by girls with a particular somatotype at the end of the school year. In particular, the following trend was found: in each pair of samples, out of all 9 characteristics studied, 5 differed by a statistically significant amount when compared, except the T- and D- samples (Table 4).

At the same time, in girls with A- and T-types, the following characteristics were VC, HR at rest, DBR, VCI,

Table 4. Differences in results of girls with different somatotypes at the end of the study

Result (points)	The name of the parameter								
	1	2	3	4	5	6	7	8	9
A - T									
t	-2.799	2.168	1.470	-2.140	-3.676	-0.204	3.164	-0.004	2.197
F	1.451	1.157	1.515	1.624	1.292	2.122	1.930	1.480	1.086
p	**0.009**	**0.038**	0.151	**0.040**	**0.001**	0.840	**0.003**	0.997	**0.035**
A - M									
t	-0.415	3.038	2.734	-2.504	-5.841	-0.038	-0.060	-1.308	3.192
F	1.760	2.070	1.050	3.060	1.030	1.710	1.120	2.160	2.410
p	0.681	**0.005**	**0.010**	**0.018**	**0.000**	0.970	0.952	0.201	**0.003**
A - D									
t	-1.437	1.707	-3.205	-2.926	-10.650	-2.272	3.646	1.043	2.262
F	1.500	1.800	1.210	1.170	2.340	1.200	3.080	2.240	1.410
p	0.166	0.103	**0.004**	**0.008**	**0.000**	**0.034**	**0.002**	0.310	**0.035**
T - M									
t	2.543	0.594	2.401	-0.790	-2.264	1.0009	-4.398	-2.392	1.640
F	1.124	1.080	1.106	1.656	1.291	1.283	1.787	3.139	1.755
p	**0.015**	0.559	**0.021**	0.434	**0.029**	0.323	**0.000**	**0.021**	0.109
T - D									
t	1.043	-0.266	-5.487	-1.729	-6.421	-3.037	1.407	1.307	0.382
F	1.030	1.560	1.830	1.380	3.030	2.600	1.590	1.510	1.300
p	0.305	0.792	**0.000**	0.094	**0.000**	**0.005**	0.170	0.201	0.705
M - D									
t	-0.958	-0.750	-7.025	-1.383	-5.061	-3.505	4.527	2.558	-0.955
F	1.090	1.680	1.650	2.290	2.350	2.030	2.850	4.750	2.290
p	0.346	0.459	**0.000**	0.177	**0.000**	**0.002**	**0.000**	**0.016**	0.347

Note: a reliably significant difference between the two means is highlighted in color

and RI. Specifying these differences, it was noted that girls with T-type had an advantage over girls with A-type in all these characteristics, except for VCI. The latter indicated better oxygen supply to the body in girls of this somatotype.

When comparing the parameters of functional characteristics of girls with A- and M-types, it was noted that the values of HR at rest, HR after exercise, RI, as well as SBR and DBR differed significantly. All parameters were better in girls with M-type, except for the last two, as in both samples they were within the age norm.

When comparing the parameters of A- and D-type girls, it was noted that HR after exercise, DBR, recovery time after exercise, VCI, and RI were significantly different. At the same time, the results in all these characteristics, except RI, were better in girls with A-type.

The parameters VC and HR after exercise differed in girls with T- and M-types, DBR, VCI, and IMIS. T-type girls had an advantage in the first characteristic, while M-type girls showed better results in the others.

As for the T- and D- samples, statistically significant differences were found in the parameters HR after exercise, DBR, and recovery time after exercise. In all cases, representatives of the T-type showed better results.

The same advantage was noted in girls with M-type when comparing the parameters HR after exercise, DBR, recovery time after exercise, VCI, and IMIS with those obtained in the sample of girls with D-type.

Discussion

The study of the parameters of physiological characteristics achieved by girls with different somatotypes while exercising outside the university due to COVID-19 quarantine and air raids during hostilities is an important task (Banakh, 2019). It is caused by trends related to the modernization of student physical education based on personalization and individualization (Kljajević et al., 2021; Annear, 2022; Ge et al., 2024). At the same time, one of the promising directions of such modernization is related to the identification of means that are interesting for girls and adequate volumes, taking into account individual characteristics (Roure et al., 2021; Hao & Yang, 2022). This direction should involve a shift from partially selective to comprehensive consideration of students' characteristics, including data synthesis and integral perception of the information received (Wiium, Säfvenbom, 2019; Banakh,

Iedynak, 2021). In this regard, the question arises of the choice and further application of an effective marker, which, based on individualization and personalization in the physical education of students, will formulate physical activity programs and assess their various characteristics (Coulter et al., 2016; Coimbra et al., 2021; Frąckiewicz, 2023). Researchers' information suggests that somatotype may be one of these markers (Cinarli & Kafkas, 2019; Campa et al., 2020). The latter is considered a conditional marker, which is an external manifestation of a person's constitution (Carter & Heath, 1990; Iedynak et al., 2021; Dinparastisaleh, R. et al., 2023). In turn, the constitution is characterized as the integrity of morphological and functional properties that are inherited and acquired, relatively stable over time, associated with the pace of individual development, peculiarities of the body's reactivity, style of activity and material prerequisites of human abilities (Katzmarzyk & Silva, 2013; Stewart et al., 2014; Silventoinen et al., 2021).

In other words, the somatotype reflects a complex of individual characteristics, which means that it is possible to assess the state of their development and take them into account when developing individual physical activity programs that are adequate to current capabilities and abilities (Pereira et al., 2017; Zorrilla-Revilla et al., 2022). Such information, although only a part of the total, is nevertheless an argument for the effectiveness and efficiency of somatotype in terms of implementing a personalized approach in the practice of physical education of students.

A certain confirmation of this is the information about the normal nature of the distribution of individual values, which was determined by the K-S test in girls with different somatotypes. These data are consistent with the results of another study (Banakh et al., 2023). Also, the results of other researchers show that the values of most morphological and functional indicators in samples of girls and boys show polymodality (Sands, 2012; Silventoinen et al., 2021). The main reason for this is the combination in one sample of two or more qualitatively different populations of the same age and sex, i.e., belonging to different somatotypes (Robinson, 2016; Weir & Vincent, 2020). At the same time, the differences are significantly reduced if the somatotype is taken into account when determining the nature of the distribution of individual values in a particular sample (Iedynak et al., 2021).

Taking into account the above, an experimental study was conducted. Already at its beginning, discrepancies were found in the parameters of the physiological characteristics of girls with different somatotypes. Differences were also found at the end of the study, and they were even more pronounced than at the beginning. Such a result was associated with a complex of reasons, one of which related to the peculiarities of morphofunctional development, namely, the clearly expressed typological dependence of the parameters of these characteristics (Ryan-Stewart et al., 2018; Cinarli et al., 2022; Sliusarchuk et al., 2022). In connection with the peculiarities of such development, it was noted that the growth and development processes begin earlier in D-type women. Compared with them, such processes begin, on average, half a year later in girls with M-type, in girls with T-type one year later, and in girls with A-type – by one and a half years (Hasiuk, 2003). Such a feature determines the unequal pace of development of various functional systems, physiological characteristics, and motor capabilities (Bacil et al., 2015; Kvintová & Sigmund, 2016; Wilmore et al., 2022). This is confirmed by our results, in particular, the differences in the values of the studied indicators. Thus, at the beginning of the study, the largest number of characteristics, the parameters of which differ by a statistically significant value, were found in pairs of samples T-A and T-D, in particular, there were 6 of them out of all 9 studied. The parameters in the pair of T-M samples were practically the same, except for VC (it was better in T-type) and DBR (it was more in M-type). Between girls with A-type and D-type, the first have a better reaction of the cardiovascular system to dosed physical exertion, the state of providing the body with oxygen (VCI), indicates the state of excessive accumulation in the muscles of structural and energy potentials that increase their working capacity (IMIS). One of the main reasons was associated with excess body weight, which is characterized by girls with D-type (Dinparastisaleh et al., 2023). Such morphological parameters negatively affect the state of the cardiovascular system, they limit physical activity, the consequence of which is different from the necessary possibility of functioning of the respiratory system and, to a certain extent, the effectiveness of the neuromuscular system (Saha, 2014; López-Sánchez et al., 2019). The period during which the experiment took place was marked by limited physical activity due to the epidemic of COVID-19, as well as air alarms. In addition, to a large extent different from the necessary volumes of physical activity were due to the lack of mandatory physical education classes for girls. Such activities, although only partially, increase the amount of physical activity in girls (Piestrzyński et al., 2021).

Data at the end of the study made it possible to obtain not only information about differences in the parameters of the physiological characteristics of girls with different somatotypes but also a change in the parameters of these characteristics during the study in representatives of each somatotype. In the latter case, it was found that in the A-type no characteristic changed by a statistically significant value, in the T-type there was a deterioration of the parameters in two characteristics (IMIS, VCI), and the detection of others at the previously achieved level. Girls with M-type improved VCI, girls with D-type increased DBR, but at the beginning, the value of the indicator also corresponded to the age norm. The main interpretation of such data is the insufficient amount of physical activity used by the girls during the study period. It is this reason that is identified as one of the main reasons for the change in physiological characteristics of both girls and boys (Zhang & Wu, 2020; James et al., 2023). At the same time, the features present in each somatotype determined the obtained results. Researchers emphasize this, in particular, they note that the state and features of development must be taken into account in practical activities, in particular, the features inherent in a certain somatotype (Katzmarzyk & Silva, 2013; Cinarli & Kafkas, 2019). One of the main reasons for the identified discrepancies lies in the unequal genetic program of the development of body systems of a girl of a certain somatotype, compared to representatives of other somatotypes. Such a development program can be adjusted to a certain extent, but only within the limits defined by it; the factors that determine such an adjustment are physical activity, nutritional features, etc. (López-Sánchez et al., 2013; Silventoinen et al., 2021).

The results of the conducted research allow us to get closer to solving the problem of offering each girl an adequate

program of physical activity, the basis of which is taking into account her characteristics. This, in turn, will contribute to strengthening the motivation of girls to engage in physical activity, because the volume and content of physical activity will reflect the wishes and capabilities of each girl, and therefore will strengthen the motivation to achieve success, the proposed normative evaluations will be realistic to achieve (Wiium & Säfvenbom, 2019; Coimbra et al., 2021).

As for the direction of further research, we see them in the determination of features related to the state of development of motor qualities, and psychophysiological indicators of girls with different somatotypes.

Conclusions

Trends in the modernization of student physical education are largely related to its personalization and individualization. One of the effective markers for the practical implementation of this is somatotype. Therefore, the study of the features that distinguish girls and boys with different somatotypes is an extremely relevant issue.

The experimental study revealed peculiarities in the parameters of physiological characteristics of first-year girls with different somatotypes. At the beginning of the study, most of the characteristics whose parameters differ significantly (at the level of $p < 0.05 \div 0.001$) were found in the pairs of samples T-A and T-D; there were 6 of them out of all 9 subjects. Almost the same parameters were found in the T-M samples, except VC (better in the T-type) and DBR (higher in the M-type). Among girls with A-type and D-type, which are marked by extreme variants of body composition components, the former has a better response of the cardiovascular system to dosed physical activity, the state of oxygen supply to the body (VCI), indicates the state of excessive accumulation in the muscles of structural and energy potentials that increase their working capacity (IMIS).

At the end of the study, it was found that girls with A-type did not improve any physiological characteristics, girls with T-type had deteriorated IMIS and VCI, girls with M-type had improved VCI, girls with D-type had increased DBR, but at the beginning, the value of the indicator also corresponded to the age norm. As for the differences, they increased at the end of the study: in each pair of samples, out of all 9 characteristics studied, 5 differed by a statistically significant amount, except for the pair of T- and D-types, where the difference was in 3 indicators (HR after loading, DBR, recovery time after loading) with the advantage of T-type representatives.

To increase the effectiveness of physical education at the university, it is advisable to differentiate it with further personalization of the content, taking into account the peculiarities of manifestation and changes in the parameters, primarily psychophysiological characteristics and physical abilities, which are characteristic of girls and boys with different somatotypes.

Conflicts of interest

No conflicts of interest exist.

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Виявлення особливостей фізіологічних характеристик дівчат із різними соматотипами за відсутності в університеті обов'язкової фізичної активності

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 11 с., 4 табл., 54 джерела.

Мета дослідження полягала у визначенні параметрів фізіологічних характеристик дівчат із різними соматотипами, яких вони досягли здійснюючи фізичну активність поза межами університету в зв'язку з карантином Covid-19 та повітряних тривог під час бойових дій в Україні.

Матеріал та методи. У дослідженні взяли участь 66 дівчат 17,8 ± 0,6 років, які належали до різних соматотипів та не мали застережень щодо використання різних обсягів фізичної активності. Для діагностики соматотипу використовували методику Штефко-Островського у модифікації С. Дарської. Одержували необхідні емпіричні дані за допомогою добре відомих функціональних тестів, що дозволяли визначити артеріальний тиск, частоту серцевих скорочень у різних ситуаціях, життєву ємність легень, життєвий індекс, силовий індекс, індекс Робінсона. Параметри цих характеристик визначали у дівчат з кожним із чотирьох наявних соматотипів протягом дослідження, а також порівнювали кожний параметр у різних соматотипах. Тестування проводили на початку (січень) та наприкінці (травень-червень) навчального семестру під час одного навчального року.

Результати. На початку, а ще більшою мірою наприкінці, навчального року, параметри досліджуваних характеристик у дівчат з кожним із наявних соматотипів відрізнялися між собою (p на рівні від 0.05 до 0.000). Використані протягом навчального року обсяги та умови реалізації фізичної активності не призвели до суттєвої зміни фізіологічних характеристик усіх дівчат, тобто параметри залишилися на досягнутому раніше рівні. Водночас відзначили існування особливостей, що зумовлені приналежністю дівчини до певного соматотипу.

Висновки. Виявлення особливостей у зміні параметрів фізіологічних характеристик дівчат із урахуванням їхніх соматотипів, є перспективним і важливим напрямком модернізації фізичного виховання в університеті. Отримані дані дозволять підвищити дієвість персоналізації змістової та диференціації нормативної основ фізичного виховання дівчат, використовуючи для цього інформацію про вияв і зміну в них параметрів різних характеристик, у тому числі фізіологічних.

Ключові слова: фізіологічні характеристики, дівчата, персоналізація, диференціація, фізичне виховання, студентки, фізична активність, Covid-19.

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Cite this article as: Banakh, V., Iedynak, G., Galamanzhuk, L., Blavt, O., Huska, M., Dmytruk, V., & Kovalchuk, V. (2024). Revealing the Peculiarities of Female Students' Physiological Characteristics with Different Somatotypes in the Absence of Compulsory Physical Activity at University. *Physical Education Theory and Methodology, 24*(5), 758-768. https://doi.org/10.17309/tmfv.2024.5.11

Received: 26.08.2024. Accepted: 19.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fizičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Determining the Impact of Adaptive Games on the Individuals' Psycho-Emotional State among Different Age Groups in Poland and Ukraine

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Accepted for Publication: September 21, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.12

Abstract

Objectives. The study aimed to determine the effectiveness of implementating projects for the introduction of adaptive sports games on the psycho-emotional state of different population groups in Poland and Ukraine.

Materials and methods. A total of 341 individuals were involved in the study: 117 children (8-12 years old), 118 middle-aged people (35-60 years old), and 116 elderly people (60 years and older). The participants of the study were divided into two groups: those who took part in the Polish project "Academic Center of Sports and Health Games for Activation of People with Special Needs" (56 children, 65 adults, 73 elderly people), and those who took part in the Polish-Ukrainian project, which was conducted directly in Ukraine, "Ukrainian Center of Occupational Therapy through Adaptive Games" (61 children, 53 adults, 44 elderly people). All study participants were engaged in adaptive games (Cornhole, Jacollo, Elastik, Kulbutto, Boccia, Paka laka) for the first time. At the beginning and end of the event on adaptive games, a survey of participants was conducted. To determine the psycho-emotional state of children, the WAM method (well-being, activity, mood) was used, and the features of adults' psychological state were assessed using the standard test AWAMW (anxiety, working capacity, activity, mood, well-being).

Results. The analysis of the obtained study results revealed positive changes in the psycho-emotional state of different population groups in Poland and Ukraine under the influence of adaptive sports games. Furthermore, the adult population, including the elderly of Poland and Ukraine, demonstrated decreased anxiety levels and a significant enhancement in activity, mood and well-being due to engaging in adaptive sports games.

Conclusions. This study emphasizes the potential of adaptive sports games to improve the mental health of different population groups. The findings also indicate the effectiveness of implementating projects for the introduction of adaptive games on the psycho-emotional state of different population groups both in Poland and Ukraine.

Keywords: psycho-emotional state, adaptive games, children, adults, elderly people, project.

Introduction

Prolonged isolation during the COVID-19 pandemic has had significant mental and physical health consequences for people around the world (Shivak et al., 2023; Veronese et al., 2023). People experienced fear of illness, uncertainty about the future, and social isolation, which contributed to worsening mental health. This was especially true for older people, teenagers and those who already had mental health problems (Alzueta et al., 2023; Hawes et al., 2022; Włostowska et al., 2024). The lack of opportunity to meet with friends and family, limited access to usual social activities, such as going to work or participating in social events, has increased the feeling of loneliness in many people. In turn, the decrease in physical activity due to the restriction of movement and the closure of gyms has led to an increase in cardiovascular problems, weight gain, sleep disorders and nutritional problems. All these consequences led to a deterioration in overall physical fitness and mental state (O'Connor et al., 2024; Dijksterhuis et al., 2022; Bogart et al., 2024).

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ТМФВ
ТОВ ОВС

The problems caused by the COVID-19 pandemic have been significantly exacerbated by the outbreak of war in Ukraine. This dual crisis has led to a significant deterioration in living conditions and, as a result, a decline in the health of many Ukrainians, especially children and young people (Chaaya et al., 2022; Lass-Hennemann et al., 2024; Riad et al., 2022). Most suffer from conditions such as post-traumatic stress disorder, anxiety and depression.

Anxiety, depression and stress increase the risk of developing post-traumatic stress disorder and complex post-traumatic stress disorder. These conditions are especially exacerbated by prolonged stress, such as war or other traumatic events. The study by Kurapov et al. (2023) showed that Ukrainians of different genders, ages and living conditions who were directly affected by military action, physical violence or experienced severe human suffering had higher levels of anxiety, depression, stress and trauma-related symptoms. At the same time, those who remained in Ukraine had significantly lower symptoms of anxiety, depression and stress compared to those who moved abroad, but this raises doubt.

Therefore, it is necessary to find new and effective means of combating the consequences of the COVID-19 pandemic and war to preserve people's mental health. Scientific research pays much attention to the impact of physical activity and sports on the mental health of people of all ages (Khan et al., 2022; Malm et al., 2019; Hoffmann et al., 2022).

In general, providing support to war victims requires a comprehensive approach, including medical, psychological, social and economic assistance. This process requires the involvement of both national and international resources, as well as active public participation.

Jain et al. (2022) took a detailed look at the aftermath of the Russian invasion of Ukraine, focusing on humanitarian actions, challenges, and opportunities for the international community in response to the crisis. The authors analyzed the situation and measures taken by European countries and international organizations, and offered recommendations for effectively overcoming the challenges associated with the war and its aftermath.

Cai et al. (2022) in their study proved the effectiveness of international cooperation and support for refugees during the Russian-Ukrainian war, namely overcoming the mental health crisis among children and adolescent refugees.

Project activities can be a very effective means of psychological support for the population, especially in times of crisis, such as a pandemic or war. Project activities can be an adaptive tool to address the specific needs of the population in crisis situations (Tijani et al., 2024). When developing and implementing projects, they collaborate with various specialists, organizations and communities, which also have a positive impact on the socialization of project participants.

Thus, this study is aimed at identifying the effectiveness of the implementation of projects for the introduction of adaptive games on the psycho-emotional state of different groups of the population of Poland and Ukraine. In Poland, the project "Academic Center for Sports and Health Games for the Activation of People with Special Needs" was implemented under the ministerial program "Social Responsibility/Perfect Science". Thanks to the transfer of experience from Polish partners, the project "Ukrainian Center for Occupational Therapy through Adaptive Games" is being implemented in Ukraine within the framework of the RITA - Region in Transition Education for Democracy Foundation competition.

Material and Methods

Participants

A total of 341 people took part in the study: 117 children (8-12 years old), 118 middle-aged people (35-60 years old) and 116 elderly people (60 years and older). The study participants were conditionally divided into two groups: those who took part in the Polish project "Academic Center for Sports and Fitness Games for the Activation of People with Special Needs" (56 children, 65 adults, 73 elderly people), and those who took part in the Polish-Ukrainian project, directly in Ukraine, "Ukrainian Center for Occupational Therapy through Adaptive Games" (61 children, 53 adults, 44 elderly people). The groups were homogeneous in terms of general characteristics, social status and health status of the study participants. All study participants were participating in adaptive games sports events for the first time (Cornhole, Jacollo, Elastik, Kulbutto, Boccia, Paka laka).

Procedure

During the work of the Polish and Ukrainian centers, a sociological survey of each participant was conducted. Also, to determine the psycho-emotional state of children, the WAM method (well-being, activity, mood) was used, and the characteristics of the psychological state of adults were assessed using the standard AWAMW test (anxiety, working capacity, activity, mood, well-being). The study participants were asked to fill in a standard self-assessment card at the beginning and end of the adaptive sports game's session. The personality self-assessment tool is presented as a registration form consisting of several lines (WAM – 30 lines; AWAMW – 40 lines), each of which contains two adjectives of opposite meanings and numbers indicating the degree of expression of each feature: 3 (strongly expressed), 2 (moderately expressed), 1 (weakly expressed).

Statistical Analysis

The research materials were processed using statistical analysis from IBM SPSS 20. The mean values were compared using the t-test for paired values. A 95 % confidence interval was chosen during data processing. The level of significance was accepted if $p \leq 0,05$.

Results

At the first stage of the study, the effectiveness of the implementation of the Polish project "Academic Center for Sports and Fitness Games for Activation of People with Special Needs" was analyzed.

The indicators of the psychological state of children after classes in adaptive sports games showed positive shifts. Thus, during the study, significant shifts were found in the children's activity indicators ($t = 31.723$; $p < 0.001$) and mood ($t = 44.161$; $p < 0.001$) (Table 1). Classes in adaptive games also had a positive effect on well-being indicators.

Table 1. Assessment of well-being, activity and mood (according to the WAM method) of Polish children aged 8-12 years at the beginning and end of adaptive sports games, points (n = 56)

№	Scales	At the beginning of the class	At the end of the class	|Δx|	Assessment of reliability	
		X ± s	X ± s	DM ± SD	t	Sig. (2-tailed)
1	Well-being	34.5 ± 7.20	50.2 ± 6.32	15.7 ± 3.98	29.429	< 0.001
2	Activity	47.3 ± 6.10	62.3 ± 4.26	15.0 ± 3.54	31.723	< 0.001
3	Mood	43.8 ± 5.4	63.4 ± 4.55	19.6 ± 3.31	44.161	< 0.001

Table 2. Assessment of anxiety, working capacity, activity, mood and well-being (using the AWAMW method) of the Polish adult population (35-60 years old) at the beginning and end of adaptive sports games, points

Indicators		At the beginning of the class	At the end of the class	|Δx|	Assessment of reliability	
		X ± s	X ± s	DM ± SD	t	Sig. (2-tailed)
Anxiety	women (n = 34)	57.8 ± 6.51	49.3 ± 4.19	8.5 ± 3.34	14.832	< 0.001
	men (n = 31)	60.4 ± 5.52	52.8 ± 4.61	7.6 ± 2.98	14.133	< 0.001
Working capacity	women (n = 34)	27.3 ± 6.68	40.2 ± 7.56	12.9 ± 3.96	19.012	< 0.001
	men (n = 31)	31.2 ± 6.58	43.5 ± 4.44	12.3 ± 4.04	16.925	< 0.001
Activity	women (n = 34)	26.4 ± 9.15	54.6 ± 6.66	28.2 ± 3.40	48.241	< 0.001
	men (n = 31)	23.8 ± 8.84	49.7 ± 6.96	25.9 ± 5.49	26.279	< 0.001
Mood	women (n = 34)	33.2 ± 5.92	50.6 ± 3.70	17.4 ± 3.47	29.107	< 0.001
	men (n = 31)	31.6 ± 6.02	48.3 ± 3.74	16.7 ± 3.21	28.924	< 0.001
Well-being	women (n = 34)	24.9 ± 6.03	42.6 ± 4.22	17.7 ± 2.55	40.339	< 0.001
	men (n = 31)	22.3 ± 6.14	37.8 ± 5.26	15.5 ± 2.03	42.637	< 0.001

Table 3. Assessment of anxiety, working capacity, activity, mood and well-being (using the AWAMW method) of Polish elderly people (60 years and older) at the beginning and end of adaptive sports games, points

Indicators		At the beginning of the class	At the end of the class	|Δx|	Assessment of reliability	
		X ± s	X ± s	DM ± SD	t	Sig. (2-tailed)
Anxiety	women (n = 43)	61.7 ± 5.53	50.1 ± 3.40	11.6 ± 2.92	25.883	< 0.001
	men (n = 30)	62.5 ± 5.66	52.8 ± 4.66	9.7 ± 3.24	16.348	< 0.001
Working capacity	women (n = 43)	16.4 ± 7.44	28.4 ± 5.49	12.0 ± 5.32	14.726	< 0.001
	men (n = 30)	18.8 ± 6.34	30.7 ± 4.19	11.9 ± 4.46	14.591	< 0.001
Activity	women (n = 43)	24.5 ± 10.45	51.4 ± 7.60	26.9 ± 6.35	27.798	< 0.001
	men (n = 30)	22.3 ± 8.34	48.2 ± 7.06	25.9 ± 5.31	26.667	< 0.001
Mood	women (n = 43)	35.7 ± 7.16	54.9 ± 5.33	19.2 ± 5.19	24.185	< 0.001
	men (n = 30)	33.1 ± 6.37	49.8 ± 3.74	16.7 ± 4.97	18.379	< 0.001
Well-being	women (n = 43)	22.7 ± 7.05	41.4 ± 6.05	18.7 ± 5.67	21.588	< 0.001
	men (n = 30)	23.8 ± 6.14	40.2 ± 5.75	16.4 ± 4.31	20.911	< 0.001

Table 2 shows changes in the psychological state of the adult population in Poland (35-60 years old) under the influence of adaptive sports games. It was found that classes using adaptive sports games had a positive effect on all participants in the study, but on women to a greater extent.

Thus, women showed a greater increase in activity indicators under the influence of adaptive sports games – by 28.2 points ($t = 48.241$; $p < 0.001$), mood – by 17.4 points ($t = 29.107$; $p < 0.001$), well-being – by 17.7 points ($t = 40.339$; $p < 0.001$), and men also showed a significant improvement in the studied indicators ($p < 0.001$).

Elderly people (60 years and older) showed a high interest in adaptive sports games events in Poland. Table 3 shows changes in indicators of the psychological state of older people under the influence of playing adaptive sports games.

Thus, in elderly women, under the influence of adaptive sports games, significant changes occurred in the indicators

Table 4. Assessment of well-being, activity and mood (according to the WAM method) of Ukrainian children 8-12 years old at the beginning and end of adaptive sports games, points (n = 61)

№	Scales	At the beginning of the class	At the end of the class	|Δx|	Assessment of reliability	
		X ± s	X ± s	DM ± SD	t	Sig. (2-tailed)
1	Well-being	31.6 ± 7.27	49.8 ± 5.10	18.2 ± 3.49	40.644	< 0.001
2	Activity	43.9 ± 7.37	64.5 ± 5.44	20.6 ± 3.26	49.405	< 0.001
3	Mood	39.4 ± 5.49	62.7 ± 3.48	23.3 ± 2.79	64.928	< 0.001

of activity (t = 27.798; p < 0.001), mood (t = 2.55; p < 0.001), well-being (t = 21.588; p < 0.001) and anxiety (t = 25.883; p < 0.001). In elderly men, reliable shifts were obtained in the indicators of activity (t = 26.667; p < 0.001), mood (t = 18.379; p < 0.001) and well-being (t = 20.911; p < 0.001).

Thus, it can be concluded that adaptive sports games had a positive impact on the psychological state and well-being of Polish residents. A survey of participants on their well-being at the beginning and end of sports events on adaptive games also revealed positive changes in respondents.

During the observation of the participants of the events, an interesting fact was revealed that those who had illnesses and disabilities stopped experiencing internal barriers: fear, shame, rejection by society. It is also worth noting the positive changes in the control over emotions and stress. Most respondents noticed a decrease in conflict situations, especially on the part of those who caused these conflicts. At the end of the sports event with adaptive games, respondents felt an improvement in their mood and noticed that they had become more open to communication. Most respondents noted that they liked this type of motor activity and were interested in learning new knowledge and skills. Thus, we can state the positive impact of adaptive sports games on well-being, as an element of quality of life, of different population groups.

In connection with the successful implementation of this project and the confirmed effectiveness of the use of adaptive games to improve the quality of life of the population, an application was submitted and won the project within the competition "RITA – Przemiany w regionie" RITA – "Region in Transition" Education for Democracy Foundation called "Ukrainian Center for Occupational Therapy Through Adaptive Games".

The project aims to implement Polish experience in the field of occupational therapy by means of adaptive games in Ukraine by opening 3 Ukrainian occupational therapy centers in partner universities of Lviv, Rivne and Kharkiv. The activities of the centers are aimed primarily at temporarily displaced persons of all ages, gender and physical abilities, including people with disabilities.

In the study of the impact of adaptive sports games, children from Ukraine showed reliable (p < 0.001) changes in all indicators of psychological state (Table 4).

Thus, the greatest changes were obtained in mood indicators, which improved by 23.3 points (t = 64.928; p < 0.001), the level of well-being increased by 18.2 points (t = 40.644; p < 0.001), and activity – by 20.6 points (t = 49.405; p < 0.001). The obtained data indicate a positive impact of adaptive games on the psycho-emotional state of children from Ukraine, which is especially important during wartime.

Also in Ukraine, a study was conducted on the level of social adaptation of children aged 8-12 during martial law. Under the influence of adaptive sports games, changes occurred in the social adaptation of children in both groups. Figure 1 shows the distribution of children by level of social adaptation at the beginning and end of adaptive sports games.

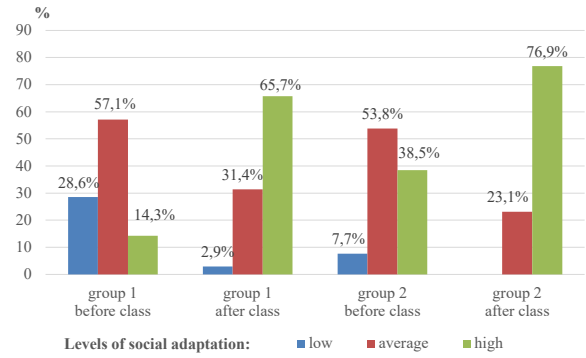

Fig. 1. Distribution of children by level of social adaptation at the beginning and end of adaptive sports games: group 1 – children who were forced to change their permanent place of residence during the war due to danger to life (n = 35); group 2 – children who did not change their permanent location (n = 26)

Thus, the number of children in group 1 with a low level of social adaptation at the beginning of adaptive sports games was 28.6 % (10 children), and at the end – 2.9 % (1 child). At that time, the number of children with a high level of social adaptation increased significantly: 14.3% (5 children) were found to be engaged in adaptive games, after – 65.7 % (23 children). Similar changes in the level of social adaptation occurred in children from group 2, that is, the number of children with a high level of adaptation increased significantly due to those with an average and low level at the beginning of the activities, and children with a low level of social adaptation were not identified at all after the activities.

The obtained data indicate a positive impact of even short-term adaptive games on the mental state and social adaptation of children, which primarily confirms the effectiveness of the implementation of this project in Ukraine, which is aimed at reducing negative phenomena during resettlement, the emergence of depression, anxiety and building connections and integration.

Adaptive sports games also affected the psycho-emotional state of the adult population of Ukraine. Table 5 presents the results of self-assessment of the level of anxiety, performance, activity, mood and well-being of mature Ukrainians (35-60 years old) at the beginning and end of adaptive sports games.

Thus, under the influence of adaptive classes, women improved their anxiety scores by 17.5 points (t = 23.018; p < 0.001), activity by 21.3 points (t = 18.726; p < 0.001) and

Table 5. Assessment of anxiety, working capacity, activity, mood and well-being (according to the AWAMW method) of the adult population of Ukraine (35-60 years old) at the beginning and end of adaptive sports games, points

Indicators		At the beginning of the class	At the end of the class	|Δx|	Assessment of reliability	
		X ± s	X ± s	DM ± SD	t	Sig. (2-tailed)
Anxiety	women (n = 28)	63.1 ± 7.13	45.6 ± 4.83	17.5 ± 4.02	23.018	< 0.001
	men (n = 25)	61.8 ± 6.49	47.3 ± 3.66	14.5 ± 3.95	18.336	< 0.001
Working capacity	women (n = 28)	28.5 ± 7.45	41.2 ± 5.29	12.7 ± 4.38	15.315	< 0.001
	men (n = 25)	30.4 ± 6.36	41.8 ± 3.73	11.4 ± 4.01	14.260	< 0.001
Activity	women (n = 28)	24.8 ± 8.58	46.1 ± 6.03	21.3 ± 6.02	18.726	< 0.001
	men (n = 25)	22.6 ± 7.28	43.5 ± 6.44	20.9 ± 5.05	20.683	< 0.001
Mood	women (n = 28)	31.4 ± 7.16	49.7 ± 3.86	18.3 ± 4.82	20.004	< 0.001
	men (n = 25)	29.4 ± 6.25	47.7 ± 4.07	18.3 ± 3.97	22.963	< 0.001
Well-being	women (n = 28)	25.3 ± 6.66	39.2 ± 5.30	13.9 ± 4.82	15.235	< 0.001
	men (n = 25)	23.1 ± 6.48	36.4 ± 5.05	13.3 ± 4.41	15.091	< 0.001

Table 6. Assessment of anxiety, working capacity, activity, mood and well-being (using the AWAMW method) of elderly people in Ukraine (60 years and older) at the beginning and end of adaptive sports games, points

Indicators		At the beginning of the class	At the end of the class	|Δx|	Assessment of reliability	
		X ± s	X ± s	DM ± SD	t	Sig. (2-tailed)
Anxiety	women (n = 26)	75.8 ± 8.61	52.3 ± 7.13	23.5 ± 4.20	28.530	< 0.001
	men (n = 18)	80.4 ± 9.62	56.8 ± 6.11	23.6 ± 6.25	16.084	< 0.001
Working capacity	women (n = 26)	15.6 ± 6.15	29.5 ± 5.52	13.9 ± 2.87	24.743	< 0.001
	men (n = 18)	17.4 ± 6.32	30.4 ± 5.93	13.0 ± 2.89	19.102	< 0.001
Activity	women (n = 26)	23.7 ± 8.16	48.3 ± 7.70	24.6 ± 4.70	26.661	< 0.001
	men (n = 18)	21.5 ± 7.69	44.1 ± 6.90	22.6 ± 2.83	33.882	< 0.001
Mood	women (n = 26)	32.4 ± 7.63	51.6 ± 6.18	19.2 ± 4.71	20.751	< 0.001
	men (n = 18)	30.7 ± 7.32	48.4 ± 4.93	17.7 ± 2.84	26.307	< 0.001
Well-being	women (n = 26)	20.4 ± 6.49	38.6 ± 5.21	18.2 ± 4.11	22.609	< 0.001
	men (n = 18)	19.8 ± 5.78	36.9 ± 5.16	17.1 ± 2.17	33.469	< 0.001

mood by 18.3 points ($t = 20.004$; $p < 0.001$). Along with this, men significantly improved their anxiety scores by 14.5 points ($t = 18.336$; $p < 0.001$), activity by 20.9 points ($t = 20.683$; $p < 0.001$) and mood by 18,3 points ($t = 22.963$; $p < 0.001$).

In men and elderly women from Ukraine, significant changes were obtained for all indicators except working capacity (Table 6). Anxiety indicators in women decreased by 23.5 points ($t = 28.530$; $p < 0.001$), in men – by 23.6 points ($t = 16.084$; $p < 0.001$). In women, the activity level increased by 24.6 points ($t = 26.661$; $p < 0.001$), mood – by 19.2 points ($t = 20.751$; $p < 0.001$) and well-being – by 18.2 points ($t = 22.609$; $p < 0.001$). Men also showed improvements in activity indicators – by 22.6 points ($t = 33.882$; $p < 0.001$), mood – by 17.7 points ($t = 26.307$; $p < 0.001$) and well-being – by 17.1 points ($t = 33.469$; $p < 0.001$).

Dicussion

This study aimed to evaluate the effectiveness of the implementation of projects for the introduction of adaptive games on the psycho-emotional state of mental health of different groups of the population of Poland and Ukraine. The main conclusion showed that participation in events on adaptive sports games had a positive effect on such indicators of the psycho-emotional state (well-being, activity, mood, working capacity and anxiety) of different groups of the population, both in Poland and Ukraine.

Psycho-emotional state is one of the key components of mental health. Chronic negative psycho-emotional state, such as constant stress, anxiety or depression, can negatively affect mental health, leading to the development of mental disorders (Polikanova et al., 2020). The current study and its results confirm the data of preliminary studies on the impact of sports activities on the mental health of people of all ages.

A study by Paluska et al. (2020), found that physical activity plays an important role in the treatment of mild to moderate mental illness, especially depression and anxiety. Results from a study by Eather et al. (2023), showed that participation in any sport (team or individual) is beneficial for improving mental health and social outcomes among adults. At the same time, team sports provide more powerful benefits for mental and social outcomes in adulthood.

Therefore, the implementation of a completely new approach to mental rehabilitation and socialization of different groups of the population, including people with special needs, occurred due to the use of adaptive games, which allowed developing new skills and integrating into social life through sports events. The main goal of adaptive sports games for different groups of the population is: solving compensatory and preventive problems; improvement of educational and health-improving functions. The main goal of the projects was the popularization of adaptive sports games among different groups of the population, including people with special needs, in order to achieve their social and psychological rehabilitation and adaptation.

Active leisure time spending through adaptive games is aimed at enriching and strengthening the social integration of people, including those with disabilities, while focusing on passive and unmotivated leisure reduces their overall vitality and contributes to deepening social isolation. Therefore, one of the important tasks of the project is the psychological guidance of people to get out of a static state, which for some has become a habit during the COVID-19 pandemic in the world and martial law in Ukraine. The principle of mental comfort is characterized by the creation of an atmosphere of relaxation and trust in the process of social and psychological rehabilitation and adaptation, which, based on internal motives, will stimulate people's activity. These data are confirmed by the study by Mulyk et al. (2024), which proved the effectiveness of using adaptive sports games on the psycho-emotional state and sensorimotor response of military personnel undergoing rehabilitation.

Currently, WAM and AWAMW methods are widely used in scientific research to determine the psycho-emotional state of individuals of all ages. The use of the WAM method is presented in the study by Romualdas et al. (2013), which presents the characteristics of well-being, activity, mood and optimism of adolescents involved in sports. The study by Polikanova et al., 2020 highlights the well-being, activity and mood of wrestling athletes under the influence of intense physical activity. The AWAMW method is presented in the works of Podrigalo et al. (2014) and Imas et al. (2021). This method was used in the study of Mulyk et al. (2024), which determined the psychological state of military personnel undergoing rehabilitation. The results show that the WAM and AWAMW methods make it easy to assess the psycho-emotional state of people of all ages. Therefore, the AWAMW method was used to determine the influence of engaged in adaptive games on the psycho-emotional state of the adult population, and the WAM method was used for children. This allowed us to obtain informative data on the assessment of anxiety, performance, activity, well-being and mood of the participants in the Polish and Ukrainian projects.

The use of adaptive games in Poland allowed children aged 8-12 years to increase their levels of well-being, activity and mood. At the same time, for the adult population (35-60 years old), engaging in adaptive games had a positive effect on the manifestation of activity, improving mood and well-being. Also, elderly people (60 years and older) significantly improved their anxiety, activity, mood and well-being indicators under the influence of adaptive games. Adaptive games implemented in Ukraine also allowed to positively influence people of different ages. Due to the event held on adaptive sports games, children aged 8-12 years improved their well-being, activity and mood indicators. Thanks to adaptive sports games, the adult population of Ukraine, including the elderly, has seen a decrease in anxiety levels and a significant increase in activity, mood and well-being.

Therefore, it can be stated that participation in the event using adaptive sports games had a positive effect on the psycho-emotional state of different groups of the population. At the same time, in our opinion, long-term training in adaptive sports games will form stable and high indicators of well-being, activity, mood, performance, and will also be reflected in a significant decrease in anxiety. Which is very important in the adaptation of the body to the stabilization of the psychological state of people.

Conclusions

This study highlights the potential of adaptive sports games to improve mental health of different population groups. The results also indicate the effectiveness of the implementation of projects to introduce adaptive games on the psycho-emotional state of different population groups both in Poland and Ukraine.

Acknowledgement

We express our sincere gratitude to all those who participated in the successful completion of this study. We are especially grateful to the project participants who agreed to participate in the study and the processing of their personal data.

We express our deep gratitude to the organizers of the projects, namely: the Ministry of National Education of Poland, within the framework of the "Social Responsibility/ Excellent Science" program and the "EDUCATION FOR DEMOCRACY" Foundation, within the framework of the Polish-American Freedom Foundation program. We are also grateful to the project coordinators and volunteers for organizing adaptive sports games and the opportunity to conduct research.

Conflicts of Interest

Authors have no conflict of interest to disclose.

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Визначення впливу занять адаптивними іграми на психоемоційний стан осіб різного віку Польщі та України

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 6 табл., 1 рис., 25 джерел.

Мета. Визначити ефективність реалізації проєктів впровадження адаптивних спортивних ігор на психоемоційний стан різних груп населення Польщі та України.

Матеріали і методи. Всього у дослідженні взяла участь 341 особа: 117 дітей (8-12 років), 118 осіб середнього віку (35-60 років) та 116 людей похилого віку (60 років і старше). Учасники дослідження були умовно поділені на дві групи: які брали участь у польському проєкті «Академічний центр спортивно-оздоровчих ігор для активізації людей з особливими потребами» (56 дітей, 65 дорослих, 73 людини похилого віку), та ті, які брали участь у польсько-українському проєкті, безпосередньо в Україні, «Український центр ерготерапії через адаптивні ігри» (61 дитина, 53 дорослих, 44 особи похилого віку). Усі учасники дослідження вперше брали участь у спортивних заходах з адаптивних ігор (Cornhole, Jacollo, Elastik, Kulbutto, Boccia, Paka laka). На початку та наприкінці заході з адаптивних ігор проводилось опитування учасників. Для визначення психоемоційного стану дітей використовувалась методика САН (самопочуття, активність, настрій), особливості психологічного стану дорослих оцінювалися за допомогою стандартного тесту ТРАНС (тривожність, працездатність, активність, настрій, самопочуття).

Результати. Аналіз отриманих результатів дослідження виявив позитивні зміни психоемоційного стану різних груп населення Польщі та України під впливом заняття адаптивними спортивними іграми. Також у дорослого населення, у тому числі й людей похилого віку, Польщі та України завдяки адаптивним спортивним іграм знизився рівень тривожності та значно підвищились показники активності, настрою та самопочуття.

Висновки. Це дослідження підкреслює потенціал адаптивних спортивних ігор для покращення психічного здоров'я різних груп населення. Також отримані результати свідчать про ефективність реалізації проєктів впровадження адаптивних ігор на психоемоційний стан різних груп населення, як в Польщі, так і в України.

Ключові слова: психоемоційних стан, адаптивні ігри, діти, дорослі, літні люди, проєкт.

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Cite this article as: Skaliy, A., Mulyk, V., Skaliy, T., Maksymova, K., & Mulyk, K. (2024). Determining the Impact of Adaptive Games on the Individuals' Psycho-Emotional State among Different Age Groups in Poland and Ukraine. *Physical Education Theory and Methodology, 24*(5), 769-776. https://doi.org/10.17309/tmfv.2024.5.12

Received: 29.08.2024. Accepted: 21.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fizičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Defining the Effect of Teachers' Medical History on their Inclusive Teaching Practice: Analyzing Feelings of Competence and Knowledge in Inclusive Physical Education

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Accepted for Publication: September 19, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.13

Abstract

Background. The process of including special students in the school system has prompted a comprehensive examination of strategies to ensure equity in school justice, the quality of learning, and the harmonious development of students' potential. The efficacy of these strategies is contingent upon the life experiences and medical backgrounds of the educators in question.

Objectives. The study aimed to evaluate the extent to which personal and family medical histories impact teachers' sense of pedagogical competence (TSPC) and their knowledge (TK) of students' physical activity management.

Materials and methods. The methodology entailed the distribution of an online questionnaire to 339 physical education and sports (PE) teachers, comprising 159 females and 180 males over the age of 21, employed in public schools at the high school and middle school levels. The measurement instrument consisted of four sections: socio-demographic characteristics, personal and family background, sense of pedagogical competence, and teacher knowledge.

Results. The findings indicate a notable prevalence of diseases such as obesity and diabetes in males compared to females, with a significant predominance in older people. It is demonstrated that gender has a particular influence on TSPC and TK in managing hypertensive students. Furthermore, older teachers and those employed in urban settings tend to exhibit greater self-efficacy, despite the absence of a statistically significant association between their initial PES training and TSPC and knowledge outcomes. There is a positive correlation between TSPC and teacher knowledge.

Conclusions. To sum it up, older teachers are more susceptible to developing illnesses such as diabetes, hypertension, and obesity. This medical history has a significant impact on the development of inclusive skills and knowledge of school-related pathologies.

Keywords: medical history, teaching skills, teachers' knowledge, inclusive physical education, inclusive pedagogy.

Introduction

The teacher plays a pivotal role in the implementation of inclusive education programs. The teacher serves as the foundation for a multitude of interventions and initiatives, designed to benefit all students in the class and to ensure their comprehensive right to education, teaching, and learning. The teacher is responsible for implementing the educational program, maintaining regular and consistent interaction with students, and monitoring their academic and training progress within the school environment (Direction des Curricula, 2019). The process of school inclusion for students with pathologies has prompted reflection on the strategies employed within this framework and the benefits derived by each student. To ensure access to mainstream education, it is imperative to establish an accessible environment, conditions that facilitate inclusive teaching and learning, and content that is both accessible and adapted to students' needs (Direction des Curricula, 2019). In order to accomplish this, it is essential to enumerate the diverse educational agents that are implicated in this process (Decision of the Minister of National Education No. 047_19 on the Inclusive Education of Pupils and Pupils with Disabilities, 2019).

The implementation of an effective and inclusive pedagogical approach for students with special needs within the context of mainstream education, including physical

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education and sports, necessitates the involvement of a diverse range of stakeholders. These include administrative and teaching staff, educational inspectors, tutoring and support professionals, parents, and the broader community (Almeida-Verdu et al., 2002; Benitez & Domeniconi, 2015; Direction des Curricula, 2019). Inclusive pedagogical practice in PES enables the establishment of equity in terms of school justice, the quality of learning, and the global and harmonious promotion of students' potential, encompassing physical, emotional, moral, and cognitive development (CSEFRS, 2015), furthermore, an individual's life experiences and medical history also influence this phenomenon (Anderson, 2006). Teachers of the disabled contribute knowledge that is not typically included in the conventional curriculum, and they illuminate aspects of education that are frequently overlooked. As they embody pedagogical approaches that prioritize school justice, interdependence, and respect for diversity, they challenge the status quo and advocate for more inclusive and equitable educational practices (Anderson, 2006).

While studies have shown that there is a notable difference in the participation of students with special educational needs in physical sports activities (Ben Rakaa et al., 2024a), as their inclusion in classes is significantly influenced by their teachers' perceptions and their sense of pedagogical competence in inclusive physical education (Ben Rakaa et al., 2024b).

In light of these considerations and the growing prevalence of chronic illnesses, particularly asthma (19 %), diabetes (3.2 %), hypertension (0.4 %) (Ministère de la Santé et de la Protection Sociale, 2018b), obesity (14 %), and overweight (8 %) in children, it is imperative to examine the potential impact of these conditions on pediatric health (Ministère de la Santé et de la Protection Sociale, 2018a). It could be argued that a body's medical history functions as a valuable and distinctive pedagogical tool. Are educators merely conduits of knowledge and "talking heads", or do bodies also educate through their medical history? This topic has piqued our interest, and we are particularly intrigued to ascertain the extent to which medical history (personal and familial) influences teachers' sense of pedagogical competence and knowledge of physical activity (PA) management towards special students, in particular those with diabetes, asthma, hypertension, obesity, and/or overweight. The objective of this study is to demonstrate the impact of PE teachers' personal and familial backgrounds on their pedagogical competence and knowledge of inclusive physical education in an educational setting.

Materials and Methods

Study Participants

The participants in this study were recruited via mailing lists provided by the Beni Mellal-Khénifra Regional Directorate of the Ministry of National Education, Preschool and Sports. Subsequently, the participants were informed via email and WhatsApp messages that their involvement in the study was entirely voluntary and that the findings would be disseminated. A total of 339 physical education and sports teachers employed in public schools consented to participate in the research, with a slight majority of male respondents (53.10 %) compared to female respondents (46.90 %). The majority of participants were within the 21-39 age bracket, with 35.40 % of individuals falling within the 21-29 age range and 28.61 % within the 30-39 age range. The proportion of participants aged 40-49 was 14.16 %, while those over 50 represented 21.83 % of the sample. The participants' professional experience is diverse, with a notable representation in the "Less than 5 years" (31.86 %) and "6 to 10 years" (28.61 %) categories. The sample comprises 14.16 % of participants with between 11 and 15 years of experience and 25.37 % with over 15 years of experience. Of the teachers surveyed, 43.07 % (n = 146) indicated that they work in urban areas, 28.61 % (n = 97) in rural areas, and 28.32 % (n = 96) in peri-urban areas. Nevertheless, 53.39 % (n = 181) of the respondents indicated that they work in college secondary schools, while 46.61 % (n = 158) reported working in qualifying secondary schools.

Measuring Instrument

A panel of five experts in the field conducted a comprehensive and meticulous assessment of the questionnaire, offering constructive feedback and recommendations pertaining to its relevance, clarity, and the suggestions provided. The online questionnaire was distributed to teachers via email and WhatsApp with the aim of recruiting participants for our study. Participation in this research was entirely voluntary. The instrument is divided into four sections. Section 1 pertains to participant characteristics, including gender, age, experience, work area, and cycle. Section 2 addresses personal and family medical history, specifically controlled and uncontrolled chronic pathology. Section 3 focuses on teachers' feelings of pedagogical competence as measured by the TSPC. Part 4 pertains to the teachers' knowledge (TK) of school pathologies and the management of special students in adapted physical activity as part of PE lessons among. The items in the final two sections are presented on a 5-point Likert scale. Cronbach's alpha for the scales measuring pedagogical competence and knowledge was 0.85 and 0.88, respectively.

Statistical Analysis

The collected results were subjected to statistical analysis using the SPSS software, version 27.0.1.0. Firstly, a descriptive analysis was conducted to ascertain the characteristics of the sample and its history. This was followed by a Chi2 test between the medical history and the age and experience of the participants, with the objective of examining whether there was a difference between the two. Subsequently, a one-factor ANOVA test was conducted to ascertain whether socio-demographic characteristics and medical history exert an influence on TSPC and TK in relation to physical activity management, for each condition. Fourthly, a correlation was established between medical history and TSPC and TK.

Results

Prevalence of personal and family medical history among PE teachers.

Table 1 illustrates that diabetic antecedents (33.64 %) are the most prevalent among the other diseases reported by

Table 1. Difference and prevalence of medical history according to gender, age and experience

Medical history		Gender			χ^2		
		Female n (% relatif)	Male (% relatif)	%/N n (% absolute)	Gender	Age	Experience
Personal	Diabetes	14 (18.92 %)	60 (81.08 %)	74 (33.64 %)	.000	.000	.000
	Obesity / Overweight	0 (0.00 %)	48 (100 %)	48 (21.82 %)	.000	.000	.000
	Asthma	14 (22.58 %)	48 (77.42 %)	62 (28.18 %)	.000	.000	.000
	High Blood Pressure	12 (33.33 %)	24 (66.67 %)	36 (16.36 %)	NS	.000	.000
	Total	40 (18.18 %)	180 (81.82 %)	220 (100 %)	-	-	-
Family	Diabetes	36 (75.00 %)	12 (25.00 %)	48 (25.00 %)	.000	.000	.000
	Obesity / Overweight	12 (25.00 %)	36 (75.00 %)	48 (25.00 %)	.000	.000	.000
	Asthma	36 (60.00 %)	24 (40.00 %)	60 (31.25 %)	.010	.000	.000
	High Blood Pressure	12 (33.33 %)	24 (66.67 %)	36 (18.75 %)	NS	.000	.000
	Total	96 (50.00 %)	96 (50.00 %)	192 (100 %)	-	-	-

Significance $p < .05$, NS. not significant

the participants. Hypertension is the most common disease among these teachers. Additionally, personal antecedents are more prevalent among men, while family antecedents are more common among women. Significant variations were observed between gender, age, and experience in the majority of cases.

Influence of medical history on feeling of pedagogical competence and teacher knowledge

Table 2 illustrates the mean values and standard deviations of teachers' sense of their pedagogical competence (TSPC) and knowledge (TK) in managing various disease types (diabetes, asthma, hypertension, and obesity) in the context of physical activity (PA), as a function of variables such as gender, age, place of work, and training cycle. Teachers over the age of 40 tend to report higher levels of competence and training than their younger counterparts. These discrepancies are particularly evident with regard to the management of diabetic, hypertensive, and obese students in the context of physical activity. Furthermore, the cycle and zone of instruction exert a significant influence on TSPC and TK.

Table 2. Effect of socio-professional factors on TSPE and TK in relation to the management of physically active students

Variable	Gender		ANOVA	Age		ANOVA	Overall	Work Area	Work cycle	Basic Training
	Female	Male		<40 years	>40 years					
TSPC – Diabetes management in PA	2.56 ± 1.30	2.88 ± 1.40	.028	2.29 ± 1.13	3.52 ± 1.39	.000	2.73 ± 1.36	.004	.000	NS
TSPC – Asthma management in PA	2.56 ± 1.41	2.72 ± 1.46	NS	2.55 ± 1.38	2.80 ± 1.53	NS	2.64 ± 1.44	.027	.000	NS
TSPC – Hypertension management in PA	2.01 ± 1.17	2.37 ± 1.40	.012	1.99 ± 1.11	2.58 ± 1.53	.000	2.20 ± 1.31	.037	.000	.000
TSPC – Obesity management in AP	4.50 ± 0.28	4.41 ± 0.28	.002	4.47 ± 0.29	4.42 ± 0.27	NS	4.45 ± 0.28	.020	NS	.039
TK – Diabetic management in AP	2.42 ± 1.45	2.85 ± 1.49	.008	2.16 ± 1.25	3.53 ± 1.46	.000	2.65 ± 1.48	.001	.000	NS
TK – Asthma management in PA	2.51 ± 1.50	2.74 ± 1.46	NS	2.50 ± 1.43	2.87 ± 1.55	.030	2.63 ± 1.48	.001	.000	NS
TK – Hypertension management in PA	2.02 ± 1.16	2.35 ± 1.44	.021	2.02 ± 1.12	2.51 ± 1.60	.001	2.19 ± 1.33	NS	.000	.000
TK – Obesity management in PA	2.47 ± 1.02	2.80 ± 1.13	.006	2.33 ± 0.93	3.20 ± 1.13	.000	2.64 ± 1.09	.000	.000	NS

All data are written as mean ± standard deviation (SD), TSPC. Teachers' sense of pedagogical competence, TK. Teachers' knowledge, AP. Physical Activity, $p < .05$. Significant, NS. Not Significant

Table 3. Effect of personal and family antecedents on TSPC and TK in relation to the management of students in physical activity

Variable	Personal medical history			ANOVA	Family medical history			ANOVA
	No	Yes	Total		No	Yes	Total	
TSPC – Diabetes management in PA	2.21 ± 1.06	4.58 ± 0.34	2.73 ± 1.36	.000	2.46 ± 1.28	4.38 ± 0.28	2.73 ± 1.36	.000
TSPC – Asthma management in PA	2.20 ± 1.22	4.60 ± 0.20	2.64 ± 1.44	.000	2.24 ± 1.27	4.50 ± 0.16	2.64 ± 1.44	.000
TSPC – Hypertension management in PA	1.88 ± 0.96	4.92 ± 0.12	2.20 ± 1.31	.000	1.94 ± 1.12	4.42 ± 0.24	2.20 ± 1.31	.000
TSPC – Obesity management in AP	4.46 ± 0.27	4.38 ± 0.36	4.45 ± 0.28	NS	4.45 ± 0.28	4.45 ± 0.32	4.45 ± 0.28	NS
TK – Diabetic management in AP	2.09 ± 1.16	4.66 ± 0.24	2.65 ± 1.48	.000	2.35 ± 1.38	4.47 ± 0.35	2.65 ± 1.48	.000
TK – Asthma management in PA	2.18 ± 1.24	4.67 ± 0.17	2.63 ± 1.48	.000	2.23 ± 1.31	4.53 ± 0.17	2.63 ± 1.48	.000
TK – Hypertension management in PA	1.87 ± 0.98	4.96 ± 0.06	2.19 ± 1.33	.000	1.92 ± 1.12	4.50 ± 0.10	2.19 ± 1.33	.000
TK – Obesity management in PA	2.67 ± 1.14	2.50 ± 0.74	2.64 ± 1.09	NS	2.63 ± 1.14	2.70 ± 0.71	2.64 ± 1.09	NS

All data are written as mean ± standard deviation (SD), TSPC. Teachers' sense of pedagogical competence, TK. Teachers' knowledge, AP. Physical Activity, $p < .05$. Significant, NS. Not Significant

Table 4. Correlation between medical history with TSPC and with TK in relation to the management of PA students at school

No	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	TSPC – Diabetes management in PA	1															
2	TSPC – Asthma management in PA	-.137*	1														
3	TSPC – Hypertension management in PA	.123*	-.124*	1													
4	TSPC – Obesity management in AP	.073	-.198**	-.04	1												
5	TK – Diabetic management in AP	.737**	.041	.279**	-.02	1											
6	TK – Asthma management in PA	-.014	.813**	-.223**	-.253**	.183**	1										
7	TK – Hypertension management in PA	.044	-.260**	.938**	.021	.214**	-.355**	1									
8	TK – Obesity management in PA	.506**	.541**	.072	-.204**	.802**	.703**	-.059	1								
9	PMH. Diabetes	.648**	.046	.044	-.016	.595**	.253**	-.172**	.596**	1							
10	PMH. Obesity/Overweight	.03	-.075	.072	-.067	.017	.188**	.092	.016	.031	1						
11	PMH. Asthma	.074	.578**	-.308**	-.300**	.214**	.635**	-.509**	.541**	.452**	.071	1					
12	PMH. Hypertension	-.016	-.211**	.547**	-.141**	-.03	-.172**	.546**	-.081	.096	.190**	-.163**	1				
13	FMH. Diabetes	.412**	-.129*	.112*	-.076	.461**	-.180**	.247**	.239**	-.215**	-.165**	-.192**	-.140**	1			
14	FMHObesity/Overweight	-.176**	-.001	-.019	.003	-.014	.045	.093	.073	-.215**	-.165**	-.192**	-.140**	.126*	1		
15	FMH. Asthma	-.162**	.508**	-.06	.01	-.014	.496**	-.002	.292**	-.245**	-.188**	-.219**	-.160**	.078	.344**	1	
16	FMH. HTA	-.032	-.061	.430**	-.049	.108*	-.134*	.416**	-.031	-.182**	-.140**	-.163**	-.119*	.190**	.190**	.141**1	

* p > .01, ** p >. 05, TSPC. Teachers' sense of pedagogical competence, TK. Teachers' knowledge, PMH. Personal medical history, FMH. Family medical history

Table 3 examines the influence of teachers' personal and family histories on TSPC and TK in terms of student PA intake. The results demonstrate significant discrepancies between teachers' personal and familial histories, particularly those with a history of diabetes, asthma, and hypertension. Teachers with a personal and/or family history will demonstrate a high level of confidence in teaching physical activities to students with pathologies.

Relationship between personal and family history with TSPC and TK

Table 4 illustrates the correlation between medical history and two pivotal variables: teachers' sense of pedagogical competence (TSPC) and their knowledge of physical activity (PA) within an educational context. The results demonstrate significant correlations ($p < 0.05$), including positive associations between personal history of diabetes ($r = 0.648$; $p < 0.05$) and obesity/overweight ($r = 0.030$; $p > 0.01$) with TSPC and TK. Furthermore, a robust correlation was identified between family history of asthma ($r = 0.508$; $p < 0.05$) and hypertension ($r = 0.430$; $p < 0.05$) and TK. Conversely, TSPC was found to be significantly correlated with TK.

Discussion

This research shows that men suffer from more pathologies than women, including diabetes 27 %, obesity 21.92 %, asthma 21 %, hypertension 16.38 %. However, the onset of pathologies in this study is significantly correlated with age progression. This indicates that individuals in their fourth decade of life and beyond are at an elevated risk of developing metabolic disorders, including diabetes and obesity, as well as cardiovascular pathologies such as hypertension. Prior research has yielded comparable findings, indicating a notable correlation between age and the prevalence of obesity, diabetes, and hypertension. A cross-sectional study conducted in four regions of low- and middle-income countries revealed that both BMI and waist circumference were reasonable predictors of the prevalence of diabetes and hypertension. Furthermore, there was a linear age-dependent trend for BMI and diabetes in men, as well as a linear age-dependent trend for waist circumference prevalence ratio. Point estimates for both types of obesity were greater in women than in men between the ages of 20 and 34. However, no statistically significant differences were observed in any other age group (Patel et al., 2016). A further study conducted in Saudi Arabia corroborated these findings (Al-Sumaih et al., 2020). However, a high BMI was linked to a heightened incidence of cognitive disorders in the elderly, irrespective of age, sex, diabetes, and hypertension (Feinkohl et al., 2018). Similarly, a study conducted in Japan demonstrated that diabetes and dyslipidemia are obesity-related comorbidities that contribute to the development of cardiovascular disease (Yamada et al., 2023).

As posited by Bandoura, competence is defined as the individual's conviction in their capacity to orchestrate and execute the requisite action plan to achieve the desired outcomes (Bandura, 2003), while the term "self-efficacy" is used to describe a person's confidence in their ability to succeed in a specific task or situation (Bandura, 2007). The construct of self-efficacy plays a mediating role in the relationship be-

tween competence and performance. This implies that despite possessing the requisite competencies to accomplish a task, an individual will not attain optimal outcomes unless they possess self-efficacy, or confidence in their abilities (Brown & Lent, 1996). While inclusive pedagogical competencies correspond to the fact that a teacher has acquired certain skills, knowledge, sense, and attitudes that enable him or her to work successfully in an inclusive classroom, including the implementation of differentiated pedagogy for diverse learners, flexible schedules, and the use of technology (Dingle et al., 2004), valuing the diversity of learners, supporting all students, collaborating with others, and promoting ongoing personal and professional growth (Nimante & Kokare, 2022). The inclusive classroom is complex, requiring a variety of pedagogical skills to promote successful learning and well-being for all children. In these classrooms, teachers face the daily challenge of meeting the educational needs of students and ensuring quality learning and personal development for every child, regardless of their situation. Therefore, inclusive teaching is not limited to traditional pedagogical skills, but positive sense of inclusive education are a precursor for teachers to be more open (Sharma et al., 2018), because these skills are the foundation for optimal self-efficacy and continuous development to achieve desired professional standards in teaching (McNeil et al., 2017; Pedersen et al., 2014). In the same vein, a study has shown that older teachers may have accumulated more experience, which allows them to develop more solid professional skills, particularly in classroom management and content adaptability, leading to better educational inclusion of all students, regardless of their situation (Darling-Hammond & Bransford, 2005; Hargreaves & Fullan, 2012), which confirms the results shown in the present study, where older teachers and those teaching in urban areas tend to feel more competent, despite their basic training in teaching physical education have no significant effect on TSPC and TK in relation to several diseases including, diabetes, asthma and obesity.

On the other hand, prolonged service without ongoing professional development and reflection can lead to ingrained pedagogical habits that make it difficult to meet the educational needs of students with chronic pathologies (Guskey, 2002). However, the different regions with varying access to training programs, specialized equipment and support staff for inclusive physical education have a direct impact on teacher training (UNESCO, 2015), as well as teachers' familiarity with the particular challenges and needs of students in their local context also influences their inclusion strategies (Tsui, 2009). While gender in our study only influenced TSPC and TK in teaching PE to asthmatic students, TK in school pathologies and TSPC in management were significantly correlated with teachers' medical, personal and family history. However, teachers with disabilities are not only able to teach students, but also to teach students about disability (Hayashi & May, 2011; Pritchard, 2010). The researchers also found that having an ESH teacher recognized as an expert in his or her field contributed more to the development of positive attitudes toward people with ESH than did exposure to disability in other scenarios (Hayashi & May, 2011; Ware et al., 2021). Others have found that, from a capability approach perspective, it's proven that those who are ESH have the freedom to explore their capabilities, they see themselves as competent teachers. Of course, it's also the case that students learn more from teachers with a medical background simply because it's a new and novel experience for them, one that elicits a more desirable response (Bryant & Curtner-Smith, 2008).

Conclusions

In conclusion, the results of our study indicate that men are more susceptible than women to developing diabetes (27 %), obesity (21.92 %), asthma (21 %), and hypertension (16.38 %). It is noteworthy that a significant correlation was observed between the incidence of these diseases and age. This indicates that individuals over the age of forty are at an elevated risk of developing metabolic diseases, including diabetes, obesity, and hypertension. Moreover, our findings illustrate that educators are not merely disseminators of knowledge; their individual and familial medical histories exert a considerable influence on their sense of pedagogical competence and their understanding of how to address the needs of students with chronic conditions in physical education (PE) classes. The findings of this study illustrate the significant influence that personal and family medical histories have on the pedagogical approach of PE teachers in the context of teaching inclusive physical education. It should be noted that this study is not without its limitations. Firstly, the risk of self-report bias may limit the generalizability of the results, as teachers with a particular interest in chronic illness may be overrepresented. Secondly, self-report of medical history may be subject to recall or social desirability bias. In conclusion, the generalizability of the study is constrained by its focus on physical education teachers in public schools in the Beni Mellal-Khénifra region.

Acknowledgment

We would like to express our deep gratitude to the Regional Directorate of the Ministry of Health and Social Protection, the Regional Directorate of National Education in Beni Mellal-Khenifra, the Royal Moroccan Federation of Sports for Persons with Disabilities, and the Regional Directorate of Solidarity, Equality and Social Development in Khouribga, in charge of promoting the rights of persons with disabilities. Their generosity in granting essential permits was crucial to the success of our project. Their invaluable support facilitated the implementation of our projects. We are deeply grateful for their cooperation and trust. The permissions provided by these esteemed partners allowed us to navigate the complexities of our research with confidence. Their commitment to advancing research and fostering collaboration has had a lasting impact on our project.

Conflict of Interest

If the authors have any conflicts of interest to declare.

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Визначення впливу анамнезу викладачів на педагогічну практику інклюзивного навчання: Аналіз відчуття компетентності та обізнаності в галузі інклюзивного фізичного виховання

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 7 с., 4 табл., 29 джерел.

Історія питання. Процес залучення учнів з особливими потребами до шкільної системи спонукав до комплексного дослідження стратегій, спрямованих на забезпечення рівності в контексті справедливості шкільної освіти, якості навчання та гармонійного розвитку потенціалу учнів. Ефективність реалізації цих стратегій залежить від життєвого досвіду та медичного анамнезу педагогів, які беруть участь у цьому процесі.

Мета дослідження. Мета дослідження полягала в оцінці ступеня впливу особистого та сімейного анамнезів на сприйняття викладачами педагогічної компетентності (СВПК) та викладацької обізнаності (ВО) щодо організації фізичної активності учнів.

Матеріали та методи. Для проведення дослідження було розповсюджено онлайн-анкету для 339 вчителів фізичної виховання і спорту (ФВС), серед яких 159 жінок і 180 чоловіків віком від 21 року, які працюють у державних школах на рівнях старшої та середньої ланок навчання. Інструмент оцінки складався з чотирьох розділів: соціально-демографічні характеристики, особистий та сімейний анамнези, відчуття педагогічної компетентності та обізнаність викладачів.

Результати. Отримані дані свідчать, що такі захворювання, як ожиріння та цукровий діабет, значно поширені серед чоловіків, ніж серед жінок, із суттєвим переважанням патологічного процесу в осіб старшого віку. Показано, що стать має особливий вплив на СВПК і ВО в рамках організації навчання учнів з гіпертонічною хворобою. Крім того, викладачі старшого віку та педагоги, які працюють у міських умовах, як правило, демонструють вищий рівень самоефективності, попри відсутність статистично значущого зв'язку між їхньою початковою підготовкою з фізичного виховання і спорту та шкалою оцінки сприйняття компетентності (Perceived Competence Scale, TSPC) та показниками якості знань. Спостерігається позитивна кореляція між шкалою оцінки сприйняття компетентності та рівнем обізнаності викладачів.

Висновки. Підсумовуючи, слід зауважити, що викладачі старшого віку є більш схильними до розвитку таких захворювань, як цукровий діабет, артеріальна гіпертензія та ожиріння. Наявність зазначеної історії хвороби має значний вплив на розвиток інклюзивних навичок і розуміння патологій, пов'язаних зі шкільною освітою.

Ключові слова: анамнез, педагогічні навички, викладацька обізнаність, інклюзивне фізичне виховання, інклюзивна педагогіка.

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Cite this article as: Ben Rakaa, O., Bassiri, M., & Lotfi, S. (2024). Defining the Effect of Teachers' Medical History on their Inclusive Teaching Practice: Analyzing Feelings of Competence and Knowledge in Inclusive Physical Education. *Physical Education Theory and Methodology, 24*(5), 777-783. https://doi.org/10.17309/tmfv.2024.5.13

Received: 15.08.2024. Accepted: 19.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

Evaluating the Effects of an 8-Week Zumba Exercise Program on Physical Fitness in Sedentary Women: A Randomized Controlled Trial

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Accepted for Publication: September 18, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.14

Abstract

Objectives. This study aimed to evaluate the impact of an 8-week Zumba exercise program on physical fitness and body composition among sedentary women. The primary goals were to assess changes in muscle mass, flexibility, back strength, cardiovascular fitness, body weight, and body fat percentage.

Materials and methods. Twenty-four female volunteers (mean age: 22.30 ± 2.10 years, height: 162.80 ± 4.00 cm) from North India were randomly assigned to either an experimental group, participating in a structured Zumba program (60-minute sessions, thrice weekly), or a control group, maintaining their usual activities. The initial and follow-up assessments comprised the measurement of height, weight, Body Fat Percentage (BFP), Body Muscle Mass (BMM), grip strength, back strength, flexibility, and Maximal Oxygen Consumption (VO_2max).

Results. The statistical analysis conducted using the SPSS 26 software and the Wilcoxon Signed-Rank Test revealed significant improvements in the experimental group. Body weight decreased from 58.20 ± 5.10 kg to 56.80 ± 5.00 kg ($p = 0.002$), body fat percentage dropped from 25.10 ± 5.80 % to 23.80 ± 6.00 % ($p = 0.03$), and body muscle mass increased from 20.40 ± 3.20 kg to 21.00 ± 3.30 kg ($p = 0.04$). Grip strength improved from 32.50 ± 5.00 kg to 33.20 ± 4.80 kg ($p = 0.05$), back strength rose from 85.00 ± 22.00 kg to 105.00 ± 25.00 kg ($p = 0.001$), flexibility increased from 31.00 ± 2.80 cm to 34.00 ± 2.50 cm ($p = 0.002$), and VO_2max increased from 41.00 ± 5.00 ml/kg/min to 44.00 ± 4.50 ml/kg/min ($p = 0.001$). No significant changes were observed in the control group.

Conclusions. The 8-week Zumba program significantly enhanced physical fitness and body composition in sedentary women, improving muscle mass, flexibility, back strength, and cardiovascular fitness. These findings support Zumba as an effective and enjoyable exercise option, promoting an active lifestyle and better health outcomes, reinforcing its role as a comprehensive fitness solution suitable for encouraging sustained physical activity.

Keywords: zumba exercise, sedentary women, physical fitness, body composition, strength.

Introduction

A sedentary lifestyle, characterized by extended periods of sitting or inactivity, minimal physical activity, and insufficient exercise, has become increasingly prevalent in modern society, with a growing body of research highlighting its detrimental impact on health and well-being. The adverse effects of a sedentary lifestyle are well-documented. As Mario and Das (2022) emphasize, physical activity is essential to daily life, and physical education aims to foster a lifelong engagement with physical activity beyond the school environment. Numerous studies have shown that prolonged sitting and physical inactivity are associated with an increased risk of cardiovascular disease, type 2 diabetes, obesity, and other chronic health conditions (Hamilton et al., 2008, Park et al., 2020, Young et al., 2016). According to a science advisory from the American Heart Association, insufficient physical activity and sedentary behavior can predict premature cardiovascular disease mortality and disease burden (Young et al., 2016). A sedentary lifestyle is characterized by prolonged sitting or inactivity, low energy expenditure, and inadequate exercise capacity (Kilinç & Kartal, 2022; Yılmaz, 2019). Researchers have warned of the damaging effects of sitting, and the topic has started to gain traction in mainstream media, highlighting the need for increased awareness and intervention (D'Abundo et al., 2015). The global prevalence of physical inactivity has reached alarming levels, with

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approximately 60 % of the adult population and two-thirds of the young population failing to engage in sufficient physical activity (Rezende et al., 2016; Kohl et al., 2012). In modern societies, the prevalence of sedentary lifestyles has become a significant public health concern, particularly among women. Research has shown that women may be more susceptible to the adverse effects of a sedentary lifestyle compared to their male counterparts (Park et al., 2020), which is why Women, in particular, may be more vulnerable to the negative impacts of a sedentary lifestyle. Sedentary women often exhibit low levels of physical activity, resulting in poor physical fitness (Yüksel & Ersoy, 2022). Sedentary lifestyles have become increasingly prevalent in modern societies, posing significant health risks (Thyfault et al., 2015). In addition, a lack of physical activity may lead to a range of health problems including muscular atrophy, osteoporosis, and decreased stamina (Çiçek et al., 2017; Rezende et al., 2015). Nevertheless, it has been emphasized that to alleviate these adverse consequences and maintain a healthy lifestyle, consistent engagement in physical exercise has been shown to induce favorable alterations in body composition and Have a beneficial effect on everyday life (Vural et al., 2010). Beyond the physical realm, the positive impact of physical activity extends to mental and psychosocial domains. Exercise is associated with a substantial reduction in the risk of mental illnesses and conditions such as anxiety and depression (Keeley & Fox, 2009). Research has demonstrated the positive effects of regular physical activity on mental health, stress reduction, and strengthening the immune system (Lu & Buchanan, 2014; Callow et al., 2020). Physical activity has long been considered beneficial to health, and regular exercise is purported to relieve stress (Childs & Wit, 2014). Substantial research links the effects of physical activity to positive physiological and psychological health outcomes (Lackman et al., 2015). Moreover, studies have shown that consistent physical exercise has beneficial impacts on mental health, stress reduction, and bolstering the immune system (Öztürk, 2021). Consistent physical exercise has been shown to have numerous benefits on various aspects of human well-being (Hackney, 2006; Gerber & Pühse, 2009; Archer & Rapp-Ricciardi, 2017; Mikkelsen et al., 2017). Additionally, it is linked to heightened psychological and social well-being (Akyurek et al., 2018). To encourage physical activity among women and improve health outcomes, it is crucial to implement methods that include new and engaging activities, such as dancing, as suggested in these guidelines and efficiency. The present analysis has shown the physiological, endocrine, cognitive, and psychological advantages associated with engaging in Zumba dancing activities (Coubard et al., 2011; Duberg et al., 2013; Kattenstroth et al., 2013). Physical freshness refers to an individual's capacity to engage in physical activities that demand strength, stamina, and flexibility (Puspodari et al., 2022). Regular Zumba workouts have a significant impact on psychological and social outcomes, body weight reduction, and increased movement strength and blood flow to muscles, making them very beneficial for students (Puspodari, Wiriawan et al., 2022). It can improve balance, strength, flexibility, and cardiovascular function, which is why it is considered an aerobic workout (Belardinelli et al., 2008). Zumba, a dynamic and exhilarating dance-fitness program, has captivated the global fitness community since its inception in the 1990s. Originating in Colombia, Zumba has transcended its roots to become a ubiquitous presence in health clubs, community centers, and living rooms around the world, attracting millions of devotees who seek an engaging and effective way to stay fit (Vendramin et al., 2016). Zumba's infectious energy and ability to engage large segments of the population have made it a subject of increasing academic interest, with researchers exploring its potential health benefits and efficacy as a fitness intervention (Domene et al., 2015). To continue effective exercise, physical activity must include more than just static muscular activation. It necessitates the preservation of a certain rhythm and movement pattern, which are essential for sustaining rhythmic motions (Civan et al., 2022). A study conducted by Barranco-Ruiz and Villa-González (2020) has shown that Zumba Fitness has several advantages for women's body composition and overall physical fitness. It has been proven to be an excellent program for increasing physical activity levels in women who are typically not very active. An examination of the research indicates that Zumba Fitness has a somewhat favorable effect on body composition, muscular strength, balance, and general quality of life. Zumba offers a gateway to cultural exploration and personal growth. It's an opportunity to transcend the boundaries of routine and embrace the full spectrum of human expression Choudhary and Dubey (2024). Zumba Fitness has emerged as a popular group exercise program that offers a unique blend of cardiovascular, strength, and dance-inspired movements. Recent research suggests that this dynamic workout modality may provide significant benefits for women's physical fitness and body composition (Donath et al., 2013). Moreover, research examining the impact of Zumba workouts on physical measurements discovered that a 12-week Zumba program had a positive influence on body metrics in women. This suggests that Zumba may help enhance body composition and facilitate weight control (Bayrakdar et al., 2020). Consistent with previous research, the findings of this study suggest that Zumba fitness can be an effective and enjoyable exercise modality for promoting physical and psychological health among overweight and obese individuals, The results demonstrated significant improvements in the participants' body composition, with reductions in body weight, body mass index, and body fat percentage (Domene et al., 2016, Ljubojević et al., 2014). Moreover, there is empirical evidence suggesting that engaging in Zumba dancing significantly improves the physical fitness of women. According to Micallef (2015), Zumba dancing, being a high-energy dance exercise, may be maintained and lead to a general improvement in fitness levels. It is worth mentioning that while current data suggests that Zumba Fitness has beneficial impacts on body composition, mental health, and cardiovascular health, there is a dearth of direct studies explicitly examining the influence of Zumba Fitness on physical fitness.

This study aims to critically assess the impact of an 8-week Zumba Fitness program on a range of physical fitness parameters in sedentary women in the northern part of India. Specifically, it will evaluate changes in weight, body fat percentage (BF%), body muscle mass (BMM), grip strength, back strength, flexibility, and maximal oxygen uptake (VO_2max). Given the increasing popularity of Zumba as a fitness modality, there is a pressing need to rigorously investigate its efficacy in improving these diverse fitness metrics. By conducting this research, the study seeks

to provide evidence-based recommendations for fitness-oriented exercise programs tailored to sedentary women, potentially enhancing overall fitness outcomes and offering valuable insights for future exercise interventions. The study hypothesizes that an 8-week Zumba exercise program will have a positive impact on various fitness parameters in sedentary women. Specifically, it posits that Zumba will significantly improve weight, body fat percentage (BF%), body muscle mass (BMM), grip strength, back strength, flexibility, and maximal oxygen uptake (VO_2 max). Each hypothesis targets a distinct aspect of physical fitness, suggesting that Zumba can enhance overall fitness outcomes by addressing these different areas.

Materials and Methods

Study Participants

Prior to the commencement of the 8-week Zumba exercise program, initial assessments were conducted to record participants' height, weight, Body Fat Percentage (BFP), Body Muscle Mass (BMM), grip strength, back strength, flexibility, and Maximal Oxygen Consumption (VO_2 max). The study then implemented an 8-week Zumba regimen, involving 60-minute sessions held three times per week. At the conclusion of this intervention, follow-up measurements were taken to evaluate any changes in height, weight, BFP, BMM, grip strength, back strength, flexibility, and VO_2 max (Table 1).

This study involved 24 female volunteers 22.30 ± 2.10 years and an average height of 162.80 ± 4.00 cm residing in the North Indian region. They were recruited from local community centres and were non-athletes with no history of diseases or sports-related injuries. Participants were randomly assigned to either the experimental group (12 participants) or the control group (12 participants). The study did not include any dietary interventions, and participants were instructed to maintain their usual eating habits throughout the study. The participants in the control

Table 1. Data Collection Tools and Procedures

Measurement Type	Description
Height, Weight, and Body Composition Measurements	Body composition values were assessed using the InBody 230 bioelectrical impedance analyzer (BioSpace, Seoul, South Korea) with a sensitivity of 0.01 kg. This analyzer provides accurate measurements of bone mass, body water, muscle mass, and segmental fat content via low electrical currents through electrodes on the hands and feet. Height was measured in centimeters with participants standing barefoot on a level, stable surface.
Hand Grip and Back Strength Measurements	Hand grip strength was assessed using the ErgoForce hand dynamometer (ErgoTech, Mumbai, India). Back strength was measured using the ErgoForce back and leg dynamometer.
Flexibility Measurement	Flexibility was evaluated using the FlexiReach test. Participants sat on the FlexiReach box and, with their hands extended forward, bent their bodies forward without bending their knees. The farthest point reached was recorded after holding for 1-2 seconds.
VO_2 max Measurement	Maximal oxygen consumption was measured using the Bruce Treadmill Protocol with modifications for local altitude conditions. The test started at 3.0 km/h with a 12 % incline, increasing every 3 minutes. Termination criteria included reaching maximal heart rate (220-age), a respiratory exchange ratio above 1.1, or exhaustion. Oxygen consumption was monitored using a Cosmed Quark CPET system, and data was collected with an integrated software program.
Zumba Exercise Program	The intervention group participated in a Zumba program consisting of a diverse choreography with various dance styles, performed three times a week at 55 % to 65 % of the target heart rate. Each session lasted 60 minutes, including 10 minutes for warm-up and cool-down exercises. The core workout included 45 minutes of Zumba steps (e.g., Bhangra, reggaeton, Hip-hop), with original Zumba music played for 4-5 minutes and 20-30 seconds rest between tracks.

Table 2. Description of the Zumba Exercise Program Components

Zumba Exercise Program	Details
Warm-Up (10 minutes)	Exercises: Dynamic stretches (e.g., shoulder rolls, hip circles) and light aerobic movements (e.g., marching in place, step-touch variations). Dance Rhythm: Slow to medium-paced Punjabi beats (90-100 BPM). Focus: Gentle muscle activation, gradually increasing heart rate.
Main Workout (45 minutes)	Number of sets: 6 sets. Duration per set: 7 minutes per set. Step Frequency: 120-135 BPM depending on dance style. Dance Styles: Hip-hop (120-125 BPM), Reggaeton (130-135 BPM), Cumbia (115-120 BPM), Bhangra (110-115 BPM). Rest between Sets: 1 minute. Music: Original Zumba tracks (4-5 minutes per track, with 20-30 seconds rest between tracks). Dance Learning Time: 1-2 minutes per set, dedicated to teaching/practicing steps.
Cool-Down (5 minutes)	Exercises: Static stretches for major muscle groups (hamstrings, quadriceps, shoulders, and back). Dance Music: Slow-paced Zumba tracks (80-90 BPM). Focus: Stretching and relaxation, holding each stretch for 20-30 seconds.

group (CG) were instructed to maintain their usual daily routines and refrain from engaging in any additional physical activities beyond their typical lifestyle. They did not follow any structured exercise or motor activity program during the 8-week period. This allowed for a clear comparison between the Zumba program's effects on the experimental group (EG) and the natural variation in fitness and body composition in the control group, ensuring that any observed changes in the EG could be attributed to the Zumba intervention. Overview of the structured Zumba exercise program, including warm-up, main workout, and cool-down details presented in Table 2.

Both groups were encouraged to maintain their normal dietary habits, and no additional instructions regarding nutrition or lifestyle modifications were provided to either group. Informed consent was obtained from all participants, with detailed explanations of the study's risks and benefits. The study adhered to ethical guidelines consistent with the Helsinki Declaration.

Statistical Analysis

Analysis of the data was conducted utilizing the Statistical Package for Social Science (SPSS) version 26 software. The Shapiro-Wilk test was employed to assess the normality of the data distribution, revealing a non-normal distribution. Consequently, the Wilcoxon Signed-Rank Test was applied to compare pre-test and post-test results within the same group. Statistical significance was determined with a threshold of $p < 0.05$.

Results

The anthropometric characteristics, grip strength, back strength, flexibility, and VO_2 max values of the sedentary women participating in the study were analyzed based on pre-test and post-test measurements.

Table 3 presents the demographic characteristics of the study participants, including mean age and mean height for both the experimental and control groups, as well as the combined data for all participants. The experimental group, consisting of 12 women, has a mean age of 22.10 ± 2.25 years and a mean height of 162.50 ± 4.25 cm. The control group, also with 12 women, has a slightly lower mean age of 22.00 ± 1.55 years and a slightly higher mean height of 164.30 ± 4.40 cm. When combined, the total sample of 24 women shows an average age of 22.05 ± 1.90 years and an average height of 163.40 ± 4.32 cm. This table provides a baseline demographic overview, ensuring that both groups are comparable in terms of age and height before the intervention.

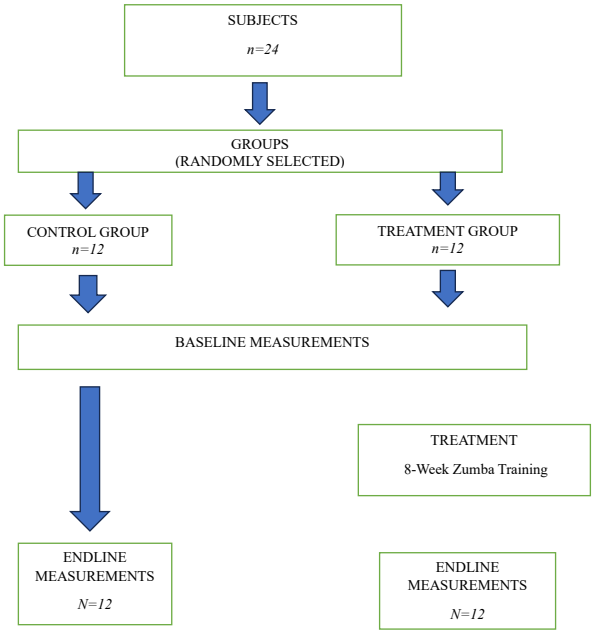

Fig. 1. Flow Chart

Table 3. Age and Height Values of the Participants

Group	Mean Age (years)	Mean Height (cm)
Experimental (n = 12)	22.10 ± 2.25	162.50 ± 4.25
Control (n = 12)	22.00 ± 1.55	164.30 ± 4.40
Combined (n = 24)	22.05 ± 1.90	163.40 ± 4.32

Table 4 displays the pre-test and post-test measurements for weight, body fat percentage (BFP), and body muscle mass (BMM) for both the experimental and control groups. The experimental group, which participated in the Zumba program, showed significant changes: their weight decreased from 58.20 ± 5.10 kg to 56.80 ± 5.00 kg ($Z = -3.15$, $p = 0.002$), BFP decreased from 25.10 ± 5.80 % to 23.80 ± 6.0 % ($Z = -2.30$, $p = 0.03$), and BMM increased from 20.40 ± 3.20 kg to 21.00 ± 3.30 kg ($Z = 2.05$, $p = 0.04$). In contrast, the control group showed no statistically significant changes in any of these measures: weight ($p = 0.65$), BFP ($p = 0.80$), and BMM ($p = 0.76$). This table highlights the effectiveness of the Zumba intervention in improving weight, body fat percentage, and muscle mass compared to the control group.

Table 4. Weight, Body Fat Percentage (BFP), and Body Muscle Mass (BMM) Values of the Participants

Measurement	Group	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	Z-Score	p-Value
Weight (kg)	Experimental	58.20 ± 5.10	56.80 ± 5.00	-3.15	0.002*
	Control	59.00 ± 4.50	59.20 ± 4.60	-0.45	0.65
BFP (%)	Experimental	25.10 ± 5.80	23.80 ± 6.00	-2.30	0.03*
	Control	24.90 ± 6.10	24.80 ± 6.20	-0.25	0.80
BMM (kg)	Experimental	20.40 ± 3.20	21.00 ± 3.30	2.05	0.04*
	Control	21.00 ± 3.50	21.10 ± 3.40	0.30	0.76

* $p < 0.05$

Table 5. Grip Strength, Back Strength, Flexibility, and VO_2 max Values of the Participants

Measurement	Group	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	Z-Score	p-Value
Grip Strength (kg)	Experimental	32.50 ± 5.00	33.20 ± 4.80	1.95	0.05
	Control	31.80 ± 4.60	32.00 ± 4.70	0.45	0.65
Back Strength (kg)	Experimental	85.00 ± 22.00	105.00 ± 25.00	-3.25	0.001*
	Control	84.50 ± 23.50	87.00 ± 21.00	-1.10	0.27
Flexibility (cm)	Experimental	31.00 ± 2.80	34.00 ± 2.50	-3.10	0.002*
	Control	30.80 ± 3.00	30.70 ± 3.10	-0.15	0.88
VO_2 max (ml/kg/min)	Experimental	41.00 ± 5.00	44.00 ± 4.50	-3.15	0.001*
	Control	40.50 ± 4.80	41.00 ± 4.90	-0.55	0.58

* $p < 0.05$

Table 5 shows the results for grip strength, back strength, flexibility, and VO_2 max before and after the 8-week Zumba intervention. For the experimental group, there was a statistically significant increase in back strength from 85.00 ± 22.00 kg to 105.00 ± 25.00 kg (Z = -3.25, p = 0.001), flexibility from 31.00 ± 2.80 cm to 34.00 ± 2.50 cm (Z = -3.10, p = 0.002), and VO_2 max from 41.00 ± 5.00 ml/kg/min to 44.00 ± 4.50 ml/kg/min (Z = -3.15, p = 0.001). Grip strength showed a marginal increase from 32.50 ± 5.00 kg to 33.20 ± 4.80 kg (Z = 1.95, p = 0.05). In contrast, the control group showed no significant changes in any of these parameters: grip strength (p = 0.65), back strength (p = 0.27), flexibility (p = 0.88), and VO_2 max (p = 0.58). This indicates that the Zumba exercise program was effective in improving physical fitness parameters compared to the control group.

Discussion

In reviewing similar studies, it has been consistently found that Zumba exercise programs positively impact body composition and physical fitness in women. A randomized controlled study demonstrated the health-enhancing efficacy of Zumba, with participants exhibiting improvements in aerobic fitness, muscular endurance, and body composition (Domene et al., 2015). Further, an investigation on the effects of an 8-week Zumba fitness program revealed significant reductions in body fat percentage and increases in lean muscle mass among female participants (Ljubojević et al., 2014). These findings suggest that Zumba represents an effective approach to improving physical fitness and body composition in women. This form of exercise has been shown to enhance the physical activity levels of sedentary women, making it a successful intervention (Barranco-Ruiz & Villa-González, 2020). In our study, Table 2 highlights the significant changes observed in weight, Body Fat Percentage (BFP), and Body Muscle Mass (BMM) among participants. Specifically, the experimental group showed a significant reduction in weight from pretest (58.20 ± 5.10 kg) to posttest (56.80 ± 5.00 kg) with a Z-score of -3.15 (p = 0.002), while the control group did not exhibit a significant change. Similarly, BFP decreased significantly in the experimental group from pretest (25.10 ± 5.80 %) to posttest (23.80 ± 6.00 %) with a Z-score of -2.30 (p = 0.03), contrasting with the control group's non-significant change. Moreover, BMM significantly increased in the experimental group from pretest (20.40 ± 3.20 kg) to post-test (21.00 ± 3.30 kg) with a Z-score of 2.05 (p = 0.04), while the control group showed no significant change. These findings align with literature reports that Zumba Fitness positively affects body composition, muscle strength, balance, and overall quality of life (Barranco-Ruiz & Villa-González, 2020). Studies have demonstrated that regular Zumba exercises can significantly improve anthropometric features in women (Bayrakdar et al., 2020). For instance, an 8-week Zumba program conducted with overweight and obese women in Malta showed effective weight loss (Micallef, 2015), similar to the significant reductions in weight and body fat percentages observed in our study (Oktay, 2015; Ljubojević et al., 2014). Regarding handgrip strength, our study found no significant differences between pretest and post-test values for both the experimental and control groups. This is consistent with previous studies that reported no significant changes in handgrip strength following Zumba exercise programs (Cugusi et al., 2015; Oktay, 2018). Conversely, significant improvements were noted in back strength, flexibility, and VO_2 max within the experimental group, as detailed in Table 3. These findings are in agreement with earlier studies that documented significant increases in maximal oxygen consumption, flexibility, and back strength following Zumba exercise programs (Oktay, 2018; Suminar et al., 2018). Luettgen et al. (2012) also reported a significant increase in VO_2 max due to Zumba exercises. Additionally, Krishnan et al. (2015) observed a 7.1 % improvement in VO_2 max after a 16-week Zumba program, and Donath et al. (2014) reported a 21 % increase in VO_2 max in the 6-minute walk test following Zumba exercise. The high-intensity, dance-based nature of Zumba likely contributes to these cardiovascular improvements, as participants engage in continuous, full-body movements that elevate heart rate and oxygen consumption (Luettgen et al., 2012). Furthermore, a randomized controlled study found that Zumba was an efficacious health-enhancing activity, with participants demonstrating significant increases in leisure-time physical activity and overall physical function (Domene et al., 2015). Together, the existing evidence suggests that Zumba represents a promising approach for improving cardiorespiratory fitness and VO_2 max among adults. Overall, our study's findings corroborate the literature, underscoring Zumba's efficacy in enhancing physical fitness parameters among sedentary women, particularly in the North Indian population. This supports the notion that Zumba dance, as a high-energy physical activity, can substantially improve general fitness levels and contribute

to better health outcomes (Micallef, 2015). Our study's results align with those of Choudhary and Dubey (2024), who found significant improvements in fitness parameters following an eight-week Zumba program. While their study focused on male college students, our research extends these findings to sedentary women in North India, demonstrating similar benefits in weight reduction, body fat percentage, muscle mass, back strength, flexibility, and VO_2 max. Specifically, the improvements in VO_2 max (from 40.44 ± 4.62 to 42.44 ± 3.12 ml/kg/min) in our study corroborate the cardiovascular benefits. The development of strategies to enhance physical activity diffusion, through effective interventions, is crucial for public health. This objective necessitates targeted health policies, shared goals, and clearly defined responsibilities. The findings from our study align with those reported by Şahin et al. (2023), who investigated the effects of an 8-week Zumba exercise program on various physical fitness components in sedentary women. Their study demonstrated significant improvements in weight, body fat percentage (BFP), body muscle mass (BMM), flexibility, back strength, and VO_2 max, similar to our findings. Notably, both studies observed significant reductions in body weight and BFP, alongside increases in BMM, flexibility, back strength, and VO_2 max in the experimental group, thereby supporting the efficacy of Zumba as a comprehensive exercise program for enhancing physical fitness in sedentary women. According to Moscatelli et al. (2023), understanding and addressing the differences in physical activity levels between male and female university students is essential for designing these strategies. The study highlights that successful public health strategies should be supported by well-planned health policies and a collaborative approach to improve physical activity among diverse populations.

Conclusions

The 8-week Zumba exercise program demonstrated significant improvements in the physical fitness and body composition of sedentary women, highlighting its effectiveness as an intervention for enhancing overall health. The study found that participants experienced notable enhancements in muscle mass, flexibility, back strength, and cardiovascular fitness, while also achieving reductions in body weight and fat percentage. These findings align with existing research on the benefits of Zumba, reinforcing its role as a beneficial, accessible, and enjoyable form of exercise that can lead to substantial health improvements. The program's success in promoting an active lifestyle among sedentary women underscores the value of incorporating Zumba into regular physical activity routines to foster better health outcomes. This study contributes to the growing body of evidence supporting Zumba as a holistic fitness solution that not only addresses various aspects of physical health but also encourages sustained engagement in physical activity due to its fun and dynamic nature. By enhancing both physical and mental well-being, Zumba proves to be a versatile exercise option suitable for a wide range of individuals, particularly those who may struggle with traditional forms of exercise. The incorporation of Zumba into fitness programs can therefore play a crucial role in public health strategies aimed at reducing sedentary lifestyles and improving quality of life.

Conflict of interest

No conflict of interest.

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Оцінка впливу 8-тижневої програми занять зумбою на рівень фізичної підготовленості жінок, які ведуть малорухливий спосіб життя: Рандомізоване контрольоване дослідження

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 5 табл., 1 рис., 52 джерел.

Мета дослідження. Мета дослідження полягала в оцінці впливу 8-тижневої програми занять зумбою на рівень фізичної підготовленості та композицію тіла серед жінок, які ведуть малорухливий спосіб життя. Головними завданнями було визначити зміни в показниках м'язової маси, гнучкості, сили м'язів спини, функціонального стану серцево-судинної системи, маси тіла та відсоткового вмісту жиру в організмі.

Матеріали та методи. У дослідженні взяли участь 24 жінки-добровольці (середній вік 22,30 ± 2,10 років, зріст 162,80 ± 4,00 см) з Північної Індії, яких було розподілено методом рандомізації до експериментальної групи, що займалася структурованою програмою із зумби (60-хвилинні заняття тричі на тиждень), або до контрольної групи, яка дотримувалася своєї стандартної активності. Початковий і подальший аналіз включав вимірювання зросту, ваги, відсоткового вмісту жиру в організмі (ВВЖО), м'язової маси тіла (ММТ), сили хвату, сили м'язів спини, гнучкості та рівня максимального споживання кисню (VO_2max).

Результати. За допомогою статистичного аналізу, проведеного із застосуванням програмного забезпечення SPSS 26 та критерію знакових рангів Вілкоксона, було встановлено значні покращення показників в експериментальній групі. Маса

тіла зменшилася з 58,20 ± 5,10 кг до 56,80 ± 5,00 кг (p = 0,002), відсотковий вміст жиру в організмі знизився з 25,10 ± 5,80 % до 23,80 ± 6,00 % (p = 0,03), рівень м'язової маси тіла підвищився з 20,40 ± 3,20 кг до 21,00 ± 3,30 кг (p = 0,04). Показник сили хвату також покращився з 32,50 ± 5,00 кг до 33,20 ± 4,80 кг (p = 0,05), сила м'язів спини зросла з 85,00 ± 22,00 кг до 105,00 ± 25,00 кг (p = 0,001), гнучкість збільшилася з 31,00 ± 2,80 см до 34,00 ± 2,50 см (p = 0,002), показник VO_2max також підвищився з 41,00 ± 5,00 мл/кг/хв. до 44,00 ± 4,50 мл/кг/хв (p = 0,001). У контрольній групі достовірних змін не спостерігалося.

Висновки. Застосування програми занять з зумби впродовж 8 тижнів сприяло значному покращенню рівня фізичної підготовленості та композиції тіла у жінок, які ведуть малорухливий спосіб життя, шляхом поліпшення показників м'язової маси, гнучкості, сили м'язів спини та функціонального стану серцево-судинної системи. Отримані результати підтверджують переваги зумби як ефективного та захоплюючого виду фізичних вправ, що сприяє активному способу життя та покращенню стану здоров'я, зміцнюючи її роль як комплексного фітнес-рішення, спрямованого на стимулювання до регулярної фізичної активності.

Ключові слова: вправи з зумби, жінки з малорухливим способом життя, фізична підготовленість, композиція тіла, сила.

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Cite this article as: Choudhary, P. K., & Dubey, S. (2024). Evaluating the Effects of an 8-Week Zumba Exercise Program on Physical Fitness in Sedentary Women: A Randomized Controlled Trial. *Physical Education Theory and Methodology, 24*(5), 784-792. https://doi.org/10.17309/tmfv.2024.5.14

Received: 24.07.2024. Accepted: 18.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fizičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Original scientific article

How do the Learning Models of Teaching Game for Understanding and Problem-Based Learning Influence Fundamental Football Skills in Physical Education? Conducting an Analysis in the Elementary School Context

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Accepted for Publication: September 30, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.15

Abstract

Objectives. The study aimed to examine the influence of Teaching Game for Understanding (TGfU) and Problem-Based Learning (PBL) learning models on the elementary school students' fundamental football skills in physical education.

Materials and methods. This study is classified as experimental research. The research design used was quasi-experimental. A total of 46 elementary school students aged 10-11 years were the samples in this study. Of the 46 samples, 23 received the PBL learning model, whereas 23 received TGfU learning.

Results. The research findings showed that: (1) there was a significant influence of the PBL learning model on fundamental football skills in physical education, with a p-value of 0.000 < 0.05; (2) the TGfU learning model demonstrated a substantial effect on fundamental football skills, with a p-value of 0.000 < 0.05; (3) a significant difference was observed between the PBL and TGfU learning models on fundamental football skills with a p-value of 0.000 < 0.05, and the difference between the two groups was 10.69.

Conclusions. According to the results obtained, the PBL and TGfU learning models have a positive influence on fundamental football skills.

Keywords: PBL, TGfU, fundamental skills, physical education.

Introduction

Physical education in elementary schools has a significant role in character development and strengthening students' fundamental movement abilities (Lander et al., 2017). Big ball games, particularly football, are used extensively in elementary school physical education (Greve et al., 2022). Fundamental football skills that schoolboy must master include kicking, controlling, dribbling, and stopping the ball (Al Ardha et al., 2018).

However, there are still various impediments to learning football in elementary school. Learning that focuses solely on mastering fundamental techniques without being combined with real-world games makes it difficult for schoolboy to apply their newly acquired skills in real-world settings (Hamari et al., 2016; Lian, 2018). In addition, a teacher-centred learning approach can lower students' interest and active participation in the learning process (Kassem, 2019).

To address this issue, there must be innovation in physical education learning models, particularly in football material. Two models of learning to explore are Teaching Games for Understanding (TgfU) and Problem Based Learning (PBL). These two learning models contain qualities appropriate for enhancing elementary school students' fundamental football skills (Abad Robles et al., 2020; Barquero-Ruiz et al., 2021).

The TgfU model emphasizes conceptual understanding of the game using a tactical approach (Harvey et al., 2020). Schoolboy participate in modified game situations to develop

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tactical comprehension and decision-making skills (Alcalá & Garijo, 2017; Wang & Wang, 2018). Meanwhile, the PBL approach highlights problem-solving in real-world football games (Aparicio-Moreno & Rivas-Gómez, 2023). Schoolboy are presented with challenges that must be resolved through a process of investigation, discussion, and decision-making (Evcimik & Oruc, 2023).

Several prior research has demonstrated that using the TgfU and PBL models in football learning can help students improve their fundamental football skills (Gil-Arias et al., 2021; Harvey et al., 2020). However, the majority of the research was conducted among high school or university students. Meanwhile, research into the impact of the TgfU and PBL models on fundamental football abilities in schoolboy in elementary school remains limited.

Therefore, the purpose of this study is to analyze the impact of the TgfU and PBL learning models on fundamental football skills in the context of physical education in elementary schools. It is expected that this research would contribute to the advancement of science, particularly in the field of physical education, as well as serve as a resource for teachers seeking to implement effective learning models to improve elementary school schoolboy fundamental football skills.

Materials and Methods

Study Participants

The sample of this study consisted of 46 elementary school schoolboy aged 10 to 11. Of the 46 samples, 23 received the PBL learning model, whereas 23 received the TGfU learning model. Furthermore, this study included two non-randomly selected groups. A pretest would be given to both groups to determine the initial conditions, followed by a posttest to determine the differences between experimental groups 1 and 2.

Study Organization

This research is classified as experimental research. This study employed a quasi-experimental research design. The purpose of this study is to directly analyze the effect of one variable on other variables, as well as to test hypotheses about cause-and-effect relationships. The following table shows the research design:

Table 1. Experimental Design Nonequivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experiment 1 (PBL)	O_1	X_1	O_2
Experiment 2 (TgfU)	O_3	X_2	O_4

Before receiving treatment, experimental groups 1 and 2 underwent initial tests to establish their fundamental football skills in physical education. Experimental group 1 was treated with PBL learning, while experimental group 2 was treated with the TGfU learning model. After both groups completed the final test, their results were compared and the differences were tested. A significant difference in scores between experimental groups 1 and 2 indicates the treatment effect. Both groups exercised three times per week for six weeks.

Statistical Analysis

The data collection tests include dribbling and short pass measurements to measure fundamental football skills. The collected data was analyzed using the Analysis of Variance (ANOVA) test at a significance level of $\alpha = 0.05$. Previously, a normality test (Shapiro-Wilk test) was performed to ensure that the data met the assumptions of normality and homogeneity of variance test (Levene's test) to verify the homogeneity of variance between groups.

Results

This study lasted one and a six weeks and involved 20 days of meetings, including one pretest, 18 treatments, and one posttest. The number of respondents was 46 students.

The following table displays descriptive statistical data from this study:

Table 2. Descriptive Data

Description	PBL Experimental Group		TGfU Experimental Group	
	Pretest	Posttest	Pretest	Posttest
N	23	23	23	23
Mean	99.39	109.09	97.57	119.78
Median	98	110	98	123
Mode	96	110	96	126
SD	5.508	6.030	3.514	10.122
Minimum	92	98	88	102
Maximum	112	123	102	139
Sum	2286	2509	2244	2755

Table 2 shows that fundamental football skills have increased in the PBL and TGfU experimental groups. The mean pretest score for the PBL experimental group is 99.39, with a posttest score of 109.09, whereas the mean pretest score for the TGfU experimental group is 97.57, with a posttest score of 119.78.

Table 3. Normality Test

Group	p-value	Sig.	Description
Pretest PBL	0.084	0.05	Normal
Posttest PBL	0.854	0.05	Normal
Pretest TGfU	0.114	0.05	Normal
Posttest TGfU	0.357	0.05	Normal

Table 3 shows the results of the normality distributions test with the Shapiro-Wilk test. Based on the data above, it is known to have a sig value > 0.05. As a result, we can conclude that the TGfU and PBL learning models for influencing fundamental football skills follow a normal distribution.

Table 4. Homogeneity Test

Group	df1	df2	Sig.	Description
Pretest-Posttest PBL	1	58	0.929	Homogenous
Pretest-Posttest TGfU	1	54	0.638	Homogenous

Table 5. Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95 % Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest PBL – Posttest PBL	-9.696	7.289	1.520	-12.848	-6.544	-6.379	22	.000
Pair 2	Pretest TGFU – Posttest TGFU	-22.217	10.220	2.131	-26.637	-17.798	-10.426	22	.000

Table 4 shows that the pretest and posttest scores for fundamental football skills in the PBL experimental group and the TGfU experimental group have p-values > 0.05, indicating that the data is homogeneous.

According to the analysis results presented in Table 5, it demonstrate that the PBL learning model has a p-value of 0.000 < 0.05, indicating a significant difference. Thus, the PBL learning approach has a considerable impact on fundamental football skills in physical education. The TGfU learning model's p-value of 0.000 < 0.05 indicates a significant difference. Thus, the PBL learning approach has a considerable impact on fundamental football skills in physical education.

Furthermore, the following table shows the differences in fundamental football skills between the PBL and TGfU experimental groups:

Table 6. Results of t-test

Group	Mean	T_{count}	p-value
PBL	109.09	4.354	0.000
TGfU	119.78		

Table 6 indicates a significant difference (tcount = 4.354, p-value = 0.000 < 0.05). As a result, the PBL and TGfU learning models differ significantly in terms of fundamental football skills. Based on the posttest average score between the PBL and TGfU experimental groups which has a difference of 10.69, it is feasible to conclude that the fundamental football skills of the experimental group treated using the TGfU learning model are better than the PBL learning model group.

Discussion

The learning program, which included 18 meetings, resulted in significant improvements in fundamental football abilities in physical education. Two learning techniques that are effective for developing fundamental football skills are Teaching Game for Understanding (TgfU) and Problem-Based Learning (PBL).

Research conducted by Parwata (2021) found that using the PBL learning models in physical education may considerably enhance primary school schoolboy fundamental football skills. The group taught utilizing PBL improved their kicking, controlling, and dribbling abilities more than the group 2 taught using conventional methods. This is due to the qualities of PBL, which enable students to actively participate in solving issues connected to football games, therefore enhancing comprehension and mastery of fundamental skills (Jia et al., 2024).

The Problem-Based Learning (PBL) learning model aims at improving students' critical thinking habits (Razak et al., 2022). PBL is a learning model in which students raise a question, the educator guides the inquiry, and students engage in dialogue to find an answer (Chen et al., 2021). PBL employs certain thinking patterns, including planned thinking, analogical thinking, systematic thinking, and generative thinking (Boelt, 2023).

On the other hand, Pratama et al. (2021) found that TGfU-based football learning units are effective in developing adaptation to long-term memory and improving the quality of students' tactical knowledge across three levels of analysis: conceptual content, conceptual sophistication, and conceptual structure. The TGfU approach, which emphasizes understanding tactics and decision-making in games, helps students acquire technical skills more comprehensively (Menglong & Qianjie, 2022). The Teaching Games for Understanding (TGfU) approach prioritizes indirect tactical approaches such as thinking, problem-solving, and initiative over rigorous technical skills (Harvey et al., 2015). The techniques used must be able to stimulate students' interest in the subject matter, compared to using direct teaching techniques (Dignath & Büttner, 2018).

In this context, the specified methods (Teaching Game for Understanding (TgfU) and 181 physical literacy (Mandigo et al., 2019). According to Barba-Martín et al. (2020), TGfU as a teaching approach can effectively help students improve Problem-Based Learning (PBL)) have common features: the formation of motivation in the educational process leads to an increase in learning opportunities, which is an element of problemoriented learning.

TGfU as a teaching approach can effectively help students improve physical literacy (Mandigo et al., 2019). According to Barba-Martín et al. (2020), the Teaching Games for Understanding (TGfU) learning approach assists both physical education teachers and their students (Barba-Martín et al., 2020). TGfU has been shown to significantly increase students' motivation to participate in sporting activities (Gaspar et al., 2021). TGfU significantly improves tactical skills and self-confidence in physical education students (Bessa et al., 2021).

According to research findings, both the PBL and TGfU learning models have a considerable impact on improving fundamental football skills in elementary school students. Although the two learning models take distinct approaches, they are both effective in enhancing students' skills to kick, control, dribble, pass, and shoot.

In practice, physical education teachers in elementary schools should consider employing these two learning models based on their students' needs and qualities.

Choosing the correct learning model can help students improve their fundamental football skills and achieve their learning objectives.

Conclusion

Based on the data and discussion, it is feasible to conclude that the PBL and TgfU learning models have significant effects on fundamental football skills. The TgfU learning paradigm can be applied in the football learning process by physical education teachers in primary schools, according to these findings. TgfU's student-centred game method has been shown to improve schoolboy enthusiasm and active involvement, resulting in the optimal acquisition of fundamental football skills. This study also proposes that innovative learning models such as TgfU and PBL should be included in primary school physical education curricula to produce more effective learning goals.

Acknowledgement

The authors would like to thank Universitas Negeri Yogyakarta for granting permission to perform the experimental study, as well as the team that assisted with the data-gathering procedure, allowing this research to be completed swiftly.

Conflict of Interest

All authors declare no conflict of interest.

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Як впливає застосування моделей організації навчального процесу «Навчання за допомогою ігрових елементів для тренування розуміння» та «Проблемно-орієнтоване навчання» на розвиток фундаментальних футбольних навичок у фізичному вихованні? Проведення аналізу в контексті початкової школи

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Реферат. Стаття: 6 с., 6 табл., 27 джерел.

Мета дослідження. Мета дослідження полягала у вивченні впливу застосування моделей навчального процесу, а саме «Навчання за допомогою ігрових елементів для тренування розуміння» (Teaching Game for Understanding, TGfU) та «Проблемно-орієнтоване навчання» (Problem-Based Learning, PBL) на засвоєння учнями початкових класів основних футбольних навичок у фізичному вихованні.

Матеріали та методи. Представлена робота відноситься до категорії експериментальних досліджень. Для проведення дослідження використовувався квазіекспериментальний метод. У дослідженні взяли участь 46 учнів початкової школи віком 10-11 років. З 46 досліджуваних – 23 учні навчалися із застосуванням моделі проблемно-орієнтованого навчання, а 23 учасники навчалися за методикою впровадження ігрових елементів для тренування розуміння.

Результати. Результати дослідження показали, що: (1) модель навчання PBL мала значний вплив на фундаментальні футбольні навички у фізичному вихованні з p-значенням 0,000 < 0,05; (2) модель навчання TGfU також продемонструвала істотний вплив на фундаментальні футбольні навички з p-значенням 0,000 < 0,05; (3) спостерігалася значна різниця між моделями навчання PBL та TGfU щодо фундаментальних футбольних навичок з p-значенням 0,000 < 0,05, а різниця між двома групами становила 10,69.

Висновки. Згідно з отриманими результатами, моделі навчання PBL та TGfU мають позитивний вплив на розвиток фундаментальних футбольних навичок.

Ключові слова: проблемно-орієнтоване навчання, навчання за допомогою ігрових елементів для тренування розуміння, фундаментальні навички, фізичне виховання.

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Cite this article as: Santoso, N., Pambudi, A. F., Prayadi, H. Y., Utami, N. S., Yudhistira, D., & Virama, L. O. A. (2024). How do the Learning Models of Teaching Game for Understanding and Problem-Based Learning Influence Fundamental Football Skills in Physical Education? Conducting an Analysis in the Elementary School Context. *Physical Education Theory and Methodology, 24*(5), 793-798. https://doi.org/10.17309/tmfv.2024.5.15

Received: 24.07.2024. Accepted: 30.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fizičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Review article

Identifying Opportunities for Developing Nature-Based Sport Tourism to Improve Health in Papua: A Bibliometric Analysis of Research Over Ten Years

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Accepted for Publication: September 9, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.16

Abstract

Objectives. This study aimed to examine research trends around nature-based tourism, event-based sports tourism, and their relationship with government policies to identify potential opportunities for sustainable sports tourism development in Papua.

Materials and methods. The methodological approach comprised using a bibliometric analysis by reviewing 997 scientific articles sourced from Scopus, PubMed, and Web of Science databases from 2014-2024. Harzing's publish or Perish software was used to sort the articles, and VOSviewer software was used to analyze the articles. The review included the number of cluster groups, research themes related to sports tourism in the year groups, research trends around nature-based sports tourism, and gaps in sports tourism development.

Results. There were eight cluster groups and five groups. The current research trends in the field of sports tourism comprise event-based sports tourism, nature tourism, the tourism industry, and social media. The research trends related to nature-based sports tourism include six keywords, namely nature-based tourism, nature connectedness, nature sport, nature-based events, nature-based recreation, and nature. Visitors, managers, communities, and governments benefit from the health and economic advantages of nature-based sports tourism. In developing nature-based sports tourism, it is essential to consider the sustainability of nature, cultural characteristics, and the form of activities offered. Local governments need to take part in efforts to develop and preserve nature-based sports tourism.

Conclusions. The development of nature-based sports tourism with traditional sports activities has a great opportunity to be enhanced. This innovation certainly needs careful planning from determining goals, human resources, risk factors, and presenting an effective promotional strategies. The involvement of local government can facilitate the implementation of this planning.

Keywords: sports tourism, sports events, government policies, research trends, bibliometric analysis.

Introduction

Sports tourism can be defined as a tourism activity followed by sports activities (Higham & Hinch, 2018). Sports activities include recreational sports presented by the tourist attraction manager. The form of recreational sports provided is adjusted to the opportunities possessed by the tourist attraction. For example, mountain tourism objects have the potential for tracking and hiking activities, marine tourism objects have the potential for surfing, diving, and water activities, and river tourism objects have the potential for tubing, kayaking, and rafting activities (Eriksson & Balslev Clausen, 2024; Philippe, 2024). The potentials of tourism objects need to be well developed, to optimize their potential (Brovina & Sallaku, 2024; Raso & Cherubini, 2023). In addition to recreational activities, sports tourism activities are also carried

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out to observe or participate in competitive sports activities and festival sports (Guan & Zhang, 2024; Guntoro et al., 2023; Kogoya et al., 2022; Sylvana Yaka Saputra et al., 2023). Sports tourism activities with this concept will bring new experiences related to sports culture in a country.

Sports tourism has contributed to the promotion of a healthy lifestyle with all forms of activities provided (Palmer et al., 2021). Outdoor activities packaged in the form of tourism have their appeal for tourists to visit (Hall & Brown, 2022). Sports activities, which have a description in the form of tiring physical activity, become more comfortable with tourism packaging (Mason & Neumann, 2024). This is because attractively presented sports tourism packaging can divert the response from sports activities. Therefore, it is important to have human resources who have high creativity and innovation in the development of sports tourism (Tsekouropoulos et al., 2022). The development of sports tourism is widely practiced by various countries because the development of tourist attractions will have an impact on increasing tourist visits (Arowosafe et al., 2022). Increased tourist visits will bring benefits to accommodation providers, culinary providers, and service providers (Raso & Cherubini, 2023; Román et al., 2022).

These benefits will ultimately have an impact on improving the economy of the community and the country (Mair et al., 2023). Tourism development with various approaches has been carried out by several countries, such as nature-based recreational sports tourism, season-based recreation, culture-based recreation, religious-based recreation, and history-based recreation (Li & Ito, 2023; Mzembe et al., 2023; Schwietering et al., 2023; Wailmi et al., 2024). All forms of development approaches must certainly continue to consider the sustainability of tourist attractions (Eriksson & Balslev Clausen, 2024). Nature-based sports tourism is a good sports tourism development developed in every country to optimize its natural potential (Guntoro et al., 2023). Natural beauty around the world has its potential and attractiveness. The design developed has its characteristics and has a great influence on attracting tourists to visit.

A review of research trends on the design of nature-based sports tourism over the past ten years is necessary to see the factors that influence success and failure. In addition, a review of previous research was conducted to look at elements that have a relationship with the basic theme. This review was also conducted to find future research gaps from the structured review. Bibliometric analysis is one analysis that can be used to find out the elements related to a topic to be examined (Ercan, 2023; Zhang et al., 2023). This analysis is widely used by previous researchers and is the basis for the research to be carried out.

Materials and Methods

This study aims to examine research trends around nature-based tourism, event-based sports tourism, and its relationship with government policy to see opportunities for sustainable sports tourism development. A literature review with a bibliometric analysis approach was used in this study.

Data Source

The data sources used in this study came from the Scopus, Web of Science, and PubMed databases. Articles published in these databases have high standards because they have gone through several assessments by competent reviewers. In addition, articles published in these databases have a high and comprehensive impact factor. So that the articles published in the databases are worthy of being used as a source of further study.

Software

The software used in this research is Harzing Publish or Perish and VOSviewer. The functions and uses of each software can be seen in the following subchapters:

Harzing Publish or Perish

Sorting articles in literature review research is very important to find quality research results. Researchers can sort articles on publisher websites manually or using software. Harzing Publish or Perish is software that functions to sort articles published on several databases. By using this software, researchers can filter articles according to the desired database. The use of keywords and database selection to filter articles greatly affects the results of the articles obtained. Some researchers use several databases to get articles that can represent the source of the study.

VOSviewer

Novelty in research is a must-have in research. VOSviewer is a software that serves to map research based on networks and to visualize research mapping. This software is widely used by researchers to find empty gaps in the research theme to be studied. With the discovery of gaps in the research theme to be studied, the research to be carried out has the potential to have novelty.

Procedure

Researchers determine the theme of the research to be studied, in this study researchers used the theme "sport tourism" as a keyword. Furthermore, researchers determine the database that will be used in sorting research articles, the databases used by researchers in this study are Scopus, Web of Science, and PubMed. Researchers used harzing publish or perish software to sort articles with predetermined themes with publication years 2014-2024.

Total of 1567 articles were obtained from the Scopus database, 577 articles were obtained from the WOS database, and 105 articles from the PubMed database. After sorting in each database, the resulting articles were then saved for sorting. Articles that are not suitable for the research topic are eliminated, and the appropriate articles are then analyzed using VOSviewer. A total of 997 articles were analyzed using VOSviewer software. Analysis using VOSviewer was carried out to obtain the distribution of the number of studies in each year, cluster groups, research trends each year, the density of research themes related to the main keywords, research trends to be analyzed more deeply, and empty gaps for further research. The theme of nature-based sports tourism research is studied more in-depth manually, considering that the theme has a large gap for further research. An overview of the research procedure can be seen in Figure 1.

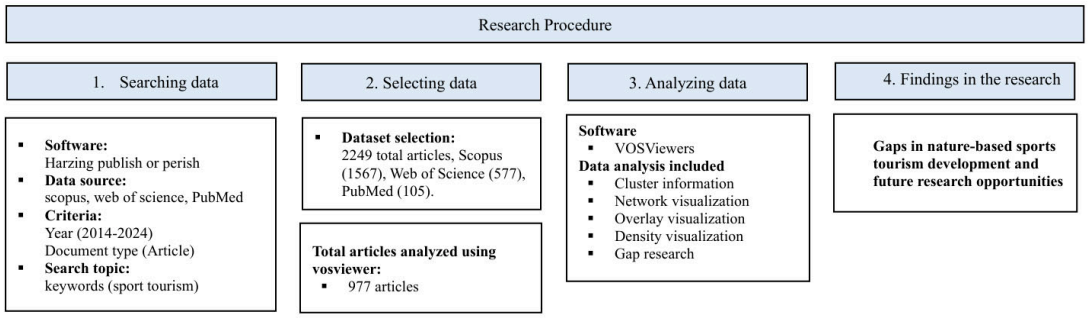

Fig. 1. Research procedure

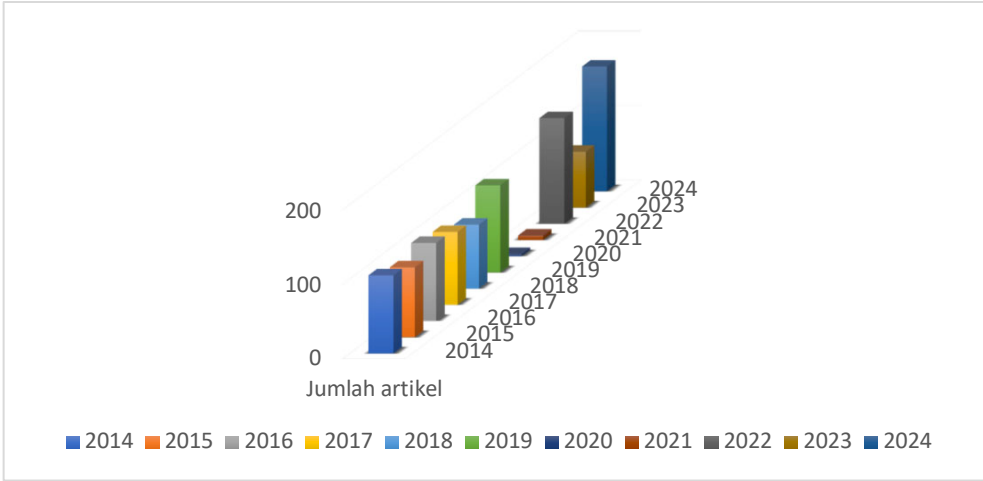

Fig. 2. Distribution of the number of articles each year Cluster group

Results

Evolution of Scientific Research on Sports Tourism 2014-2024

The distribution of the number of studies related to sports tourism each year can be seen in Figure 2. In 2014 there were 105 articles related to research topics, in 2015 there were 94 articles related to research topics, in 2016 there were 105 articles related to research topics, in 2017 there were 98 articles related to research topics, in 2018 there were 86 articles related to research topics, in 2019 there were 117 articles related to research topics, in 2020 there were 3 articles related to research topics, in 2021 there were 6 articles related to research topics, in 2022 there were 142 articles related to research topics, in 2023 there were 75 articles related to research topics, and in 2024 there were 168 articles related to research topics.

The results of the VOSviewer analysis in the form of network visualization can be seen in Figure 3. Each keyword is marked with a circle label that has been set by the system. The size of the circle label indicates the number of studies that have studied the keyword. Some keywords are not visible in the image because of the overlap between keywords. The color of each circle or label indicates the cluster group. The net lines between keywords show the relationship between keywords.

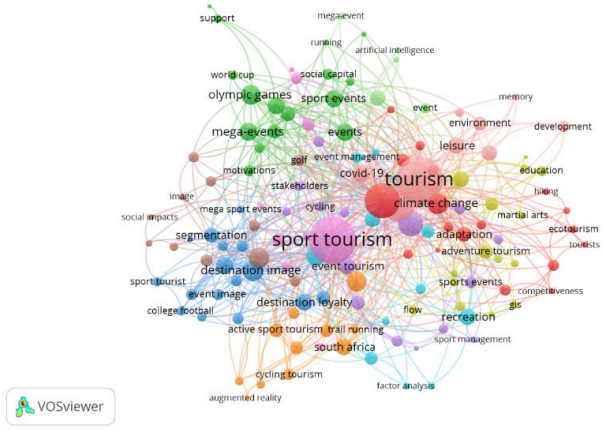

Fig. 3. Network visualization

Based on the results of the analysis using VOSviewer, a network visualization with eight cluster groups was obtained. Each cluster consists of interconnected keywords. Cluster groups can be seen based on the color of the net on each keyword or element depicted. Cluster grouping can be seen in Table 1.

Table 1. Elements in each cluster

No	Cluster	Elmenets
1	Red cluster	Sports tourism, tourism, covid-19, destination management, China, leisure, climate change, sporting events, winter tourism, hiking, active tourism, adaptation, sport, social media, destination competitiveness, heritage, environment, physical activity, memory, development, hiking, authenticity, ecotourism, tourists, winter sport, ski resorts, competitiveness, adaptation, social impact, active tourism
2	Pink cluster	Sports tourism, surf tourism, serious leisure, travel behavior, event experience, sport event, mega event, media, event leveraging
3	Blue cluster	Rural tourism, event management, perception, sustainable tourism, sustainable development, nature-based tourism, recreation, urban development, market segmentation, factor analysis, physical education, motivation, place attachment, sport tourists, challenge football, event image, destination loyalty, tourist satisfaction, destination image, event quality, perceived value, nostalgia, cluster analysis, segmentation, sport event tourism, behavioral intentions, mega sports event
4	Green cluster	Quality of life, support, world cup, mega-event, service quality, running, artificial intelligence, tourism, industry, management, Olympic games, legacy, sport event, sport, event, volunteers, motivations, Olympic, impact
5	Yellow cluster	Gender, nature, education, economic impact, cultural tourism, martial art, adventure tourism, surfing, content analysis, low, wellness tourism, gis, ice and snow tourism
6	Purple cluster	Literatur review, sport management, leveraging, innovation, sustainability, event tourism, cycling, tourism development, surf tourism, community development, stakeholders, entrepreneurship, sports event
7	Orange Cluster	Destination marketing, destination, active sport tourism, event portfolio, trail running, mountain biking, south Africa, cycling tourism, revisit intention, virtual reality, augmented reality
8	Brown cluster	Golf, FIFA World Cup, social exchange theory, image, social impact, quality, scale development, golf tourism, loyalty, satisfaction, experience

Table 2. Theme grouping for each year

No	Years	Elements
1	2014-2015	Memory, heritage, ecotourism, nature-based tourism, mountain biking, travel behavior, scale development, social impact, rural tourism, leveraging, legacy.
2	2016-2017	Service quality, management, legacy, event, sport event, event, mega event, cycling, image, quality, segmentation, golf tourism, serious leisure place attachment, economy impact, social impact, cultural tourism, martial art, tourists, content analysis, world cup.
3	2018-2019	Support, mega-event, running, media, world cup, mega event, social capital, sports events, sport, volunteers, motivations, golf, destination management, tourism, stakeholders, satisfaction, destination marketing, urban development, south Africa, market segmentation, trail running, augmented reality, event portfolio, recreation, ski resorts, winter sport, adventure tourism, winter tourism, climate change, China, leisure.
4	2020-2021	Quality of life, Olympics, impacts, motivations, FIFA World Cup, social exchange theory, tourism development, behavioral intentions, destination image, event quality, experience, destination loyalty, college football, sports tourism, lifestyle, revisit intention, virtual reality, physical education, systematic review, tourist satisfaction, event tourism, event leveraging, sports events, adaptation, gis, sustainable development surfing, competitiveness, innovation, hiking, education, destination management, destination competitiveness, education, physical activity, environment, ice and snow tourism.
5	2022-2024	Event image, event leverage, literature review, flow, decision making, entrepreneurship, covid-19, gender, nature, social media, tourism industry, artificial intelligence.

Research Trends in the Year Group

Overlay visualization illustrates the history of research. Based on the results of the analysis using VOSviewer, the overlay visualization results are obtained from 2014 to 2024. The color setting on each label or keyword shows the history of the research topic. The blue color shows research in 2014-2015, light blue color shows research in 2016-2017. The green color indicates research in 2018-2019, the green color indicates research in 2020-2021, and the orange color indicates research in 2022-2024. An overview of the distribution of overlay visualization can be seen in Figure 4.

The overlay visualization results show an overview of keywords or research elements related to sports tourism based on the year. The grouping of elements or keywords based on history or years of research can be seen in Table 2.

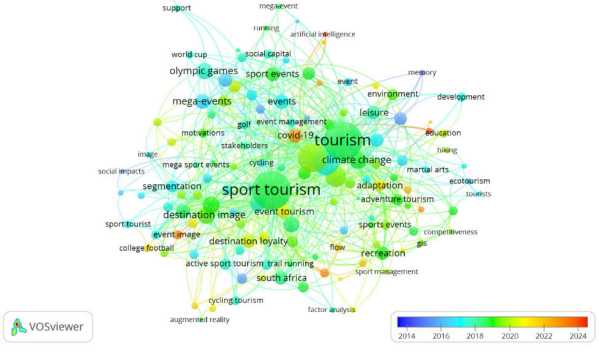

Fig. 4. Overlay visualization

Research Trends Around Nature-Based Sports Tourism

The research topics studied in more depth are research trends around nature-based sports tourism. The findings and suggestions on the research related to the chosen theme are presented in Table 3 below.

Table 3. Research findings and suggestions around nature-based sports tourism

No	Name/Years	Methods	Findings and suggestions
1	Klauco et al., 2017	Planning or part of the development method	Land planning for recreational activities based on an ecological approach includes spatial analysis, interpretation, evaluation, and review of recreational activity suggestions. Recreational activities are adapted to the season. Nature-based recreational activities include skiing, hiking, water sports, and fishing. The recreational activities that can be presented every season are therapeutic. All activities provided do not cause any impact (Bausch & Unseld, 2018).
2	Bausch & Unseld, 2018	Qualitative	Winter sports tourism is an economic sector supplier across the world's mountain ranges. Skiing is the activity of choice for winter visitors. In addition, activities related to relaxation and the development of sustainable winter sports tourism are expected by visitors.
3	Huhta & Sulkava, 2014	Longitudinal study	Nature-based recreational tourism in and near protected areas has negative impacts on the environment, biodiversity, and landscape fragmentation in the absence of clear government regulation. This can be caused by disturbances caused by recreational activities such as making campfires.
4	Stojanović et al., 2024	Prism of Sustainability (PoS) model	Nature, socio-cultural, sociocultural, and tourist destinations are factors that influence residents' and visitors' satisfaction with sustainable tourism. Forms of tourism such as recreational sports, ecotourism, bird watching, events, culture, and gastronomy, can provide environmental, economic, and social benefits in protected areas that are used as tourist attractions.
5	Ponting & O'Brien, 2014	Evaluation	The importance of government regulation in maintaining the sustainability of nature-based sports tourism (nature-based tourism).
6	Houge Mackenzie et al., 2023	Literature review	Adventure sports tourism positively influenced hedonic and eudaimonic psychological well-being through the satisfaction of basic psychological needs and connectedness with nature. Future research on the development of adventure sports tourism would do well to examine its benefits on psychological well-being (nature connectedness).
7	Wagner, 2024	Intersectionality of study	Geographical characteristics and cultural characteristics affect the character of tourism objects. The role of tour guides is very important in giving an impression to tourists. A good impression given by a tour guide can have an impact on return visits. (nature sport).
8	Schwietering et al., 2023	Survey	The importance of the diversity of digital tools used to support outdoor activities. Tourism managers need to consider the use of digital tools to monitor the presence of visitors to be effective in traveling in nature conservation tourism objects (nature sport).
9	Melo & Gomes, 2017	Survey	Nature and adventure were indicated as the main reasons for engaging in nature sports, but time and cost constraints were the main obstacles to participating in nature sports (nature sport).
10	Eriksson & Balslev Clausen, 2024	Survey	Sporting events have impacts such as waste and greenhouse gas emissions. An even bigger impact is damage to the environment and public facilities. Participants generally assign responsibility for these issues to the event organizers. However, it is important to educate participants or visitors to sport tourism events to preserve nature and public facilities (nature-based event).
11	Román et al., 2022	Literature review	Surfing-related research topics have continued to grow since the 21st century, and the management of these tourist destinations needs to be considered to ensure the sustainability of tourist attraction development. Good collaboration between managers, communities, and stakeholders is a factor that can affect the sustainability of tourism (nature-based recreational).
12	Rojo-Ramos et al., 2023	Survey	Tourist attraction managers need to study the characteristics of tourists who visit, this is done to adjust the services that are adjusted to the tourist attraction. That way tourist visits will increase (Nature).
13	Štumpf & Kubalová, 2024	Linear Model with a logit link function	Environmental changes and environmental conditions affect visitor satisfaction. Tourist attraction managers need to carry out promotions related to the activities presented in nature tourism. Sports activities to maintain health and lifestyle are activities that many tourists want.
14	Philippe, 2024	Study Case	The role of sports associations in preserving the environment amid the development of recreational sports in the natural environment is good work. Natural damage can occur in the process of developing tourist attractions if the use of heavy equipment is not supervised.
15	Quezada–Sarmiento et al., 2024	Evaluation	Adventurous nature activities organized through travel to places that are natural and exotic, accessible and rugged, generating adrenaline when doing extreme sports.

Discussion

The nature-based sports tourism trend is a tourism activity that presents outdoor activities in the form of recreational sports. Recreational sports are packaged in the form of adventure, hiking and camping, water games, surfing, skiing, and others (Quezada–Sarmiento et al., 2024; Román et al., 2022). The specified activities are generally adapted to the conditions of natural attractions, culture, geographical characteristics, and sociocultural (Stojanović et al., 2024). The selection of activities is also determined by adjusting the season (Bausch & Unseld, 2018). Activities carried out in nature will certainly affect the sustainability of nature. Risk factors for natural damage to tourist attractions are often found, so supervision and regulation from tourist attraction managers and the government are needed (Philippe, 2024). Regulatory rules related to sports tourism activities in the natural environment need to be emphasized to managers and users by establishing regulations for negligent acts of managers or visitors that have an impact on environmental damage (Hu et al., 2022).

Sports tourism activities in nature can relax the mind which will have a positive effect on psychological conditions that are stressed due to work. Not infrequently the activities provided in nature-based sports tourism can spur adrenaline. Nature-based sports tourism activities are also beneficial for improving physical health (Houge Mackenzie et al., 2023). This is because physical activity will affect fitness. The benefits of nature-based sports tourism are not only obtained by visitors, but the surrounding community, managers, and government also benefit from nature-based sports tourism activities (Mason & Neumann, 2024). The management of nature-based sports tourism requires many competent natural resources in the fields of management, finance, promotion, and law (Román et al., 2022). In its implementation, it certainly requires many employees in each field, which in turn will create new jobs (Qwatekana & Tshikovhi, 2024). In addition, the surrounding community also gets a positive impact from selling souvenirs and providing accommodation in the form of lodging and transportation (Tiku & Shimizu, 2020). The many benefits of organizing nature-based sports tourism open up opportunities for communities and governments in areas that have natural potential (Huhta & Sulkava, 2014). However, nature conservation needs to be considered in the development of nature-based sports tourism.

The Gap in Sports Tourism Development

Based on a review of previous research on nature-based sports tourism, the research trend has good benefits for visitors, organizers, communities, and governments (Ponting & O'Brien, 2014). Although the activities organized in some countries include cultural and sociocultural-based activities, the activities presented are only adapted to the needs of activities in certain seasons of nature (Stojanović et al., 2024; Wagner, 2024). The difference in culture and seasons in European countries and Indonesia raises new opportunities for the development of sports-based tourism. Opportunities for the development of nature-based tourism in Indonesia are by including elements of culture and local wisdom as a specialty (Guntoro et al., 2023). Indonesia is one of the countries in the Southeast Asian region that has a variety of cultures and traditional games (Kusumawardhana et al., 2021; Prayitno et al., 2024). This diversity can be expressed in the development of nature-based sports tourism, considering that the natural beauty in Indonesia is also diverse and spread throughout the territory of the unitary state of Indonesia.

Opportunities for the development of nature-based sports tourism with a cultural approach and traditional games need to be launched and planned. Planning the development of nature-based sports tourism requires collaboration from developers, communities, sponsors, academics, and the government (Philippe, 2024; Ponting & O'Brien, 2014). Reviewing opportunities and risk factors from a variety of perspectives is necessary for a good nature-based sports tourism design (Klauco et al., 2017; Wagner, 2024). With an innovative nature-based sports tourism design, it will have a positive impact on tourist interest in visiting. Increased tourist visits will have a positive impact on the economy of the community and the country.

Conclusions

Visitors, managers, communities, and governments benefit from nature-based sports tourism. Sports in tourist attractions can have a positive effect on the physical and psychological health of visitors. Managers and surrounding communities benefit economically from the development of nature-based sports tourism. The development of nature-based sports tourism needs to consider the preservation of nature, cultural characteristics, and the form of activities offered. Local governments need to take part in efforts to develop and preserve nature-based sports tourism. The development of nature-based sports tourism with traditional sports activities has a great opportunity to be developed. This innovation certainly needs careful planning from determining goals, human resources, risk factors, and promotion. This planning will certainly run well with the support of the local government.

Acknowledgment

The research team would like to thank the Ministry of Education, Culture, Research and Technology (KEMENDIKBUDRISTEK) for research funding through the Directorate of Research, Technology and Community Service (DRTPM) with the main contract number 046/E5/PG.02.00.PL/2024 and derivative contract number 545/UN20.2.1/PG/2024. The research team would also like to thank the Institute for Research and Community Service (LPPM) of Cenderawasih University for facilitating the process of applying for research grants and community service in 2024.

Conflict of interest

All authors declare no conflict of interest.

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Визначення можливостей розвитку спортивного природно-орієнтованого туризму щодо покращення стану здоров'я в Папуа: Бібліометричний аналіз досліджень за десять років

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 3 табл., 4 рис., 38 джерел.

Мета дослідження. Метою цього дослідження було вивчення наукових тенденцій у галузях природно-орієнтованого туризму, спортивного подієвого туризму, а також їхнього зв'язку з державною політикою щодо визначення потенційних можливостей для сталого розвитку спортивного туризму в Папуа.

Матеріали та методи. Методологічний підхід включав в себе проведення бібліометричного аналізу шляхом огляду 997 наукових статей, отриманих з наукометричних баз даних Scopus, PubMed та Web of Science у період з 2014 по 2024 рік. Для сортування статей було застосовано програмне забезпечення Harzing's publish or Perish, а для аналізу статей — програмне забезпечення VOSviewer. До аналізу було включено кількість кластерних груп, дослідницькі тематики, пов'язані зі спортивним туризмом у відповідних групах за роками, дослідницькі тенденції щодо спортивного природно-орієнтованого туризму, а також наявні прогалини у розвитку спортивного туризму.

Результати. Сформовано вісім кластерних груп та п'ять підгруп. Сучасні дослідницькі тенденції у сфері спортивного туризму охоплюють спортивний подієвий туризм, природний туризм, туристичну індустрію та соціальні медіа. Дослідницькі тенденції, пов'язані зі спортивним природно-орієнтованим туризмом, складаються з шести ключових слів, а саме: природно-орієнтований туризм, зв'язок з природою, заняття спортом на природі, подієві заходи на природі, оздоровчий

відпочинок на природі та природнє середовище. Відвідувачі, менеджери, громади та уряди користуються оздоровчими та економічними перевагами спортивного природно-орієнтованого туризму. Розвиваючи спортивний природно-орієнтований туризм, важливо враховувати питання сталості природного середовища, культурних особливостей та форми запропонованих видів активності. Місцеві органи влади повинні брати участь у заходах, спрямованих на розвиток та збереження спортивного природно-орієнтованого туризму.

Висновки. Розвиток спортивного природно-орієнтованого туризму з традиційними видами спорту має велику перспективу для подальшого вдосконалення. Така інновація, безумовно, потребує ретельного планування, починаючи з визначення цілей, людських ресурсів, факторів ризику та представлення ефективних стратегій популяризації. Залучення органів місцевого самоврядування може сприяти реалізації планування цього процесу.

Ключові слова: спортивний туризм, спортивні події, державна політика, дослідницькі тенденції, бібліометричний аналіз.

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Cite this article as: Guntoro, T. S., Prasetyo, Y., Putra, M. F. P., Nurhidayah, D., Sinaga, E., Yuliana, E., & Nanda, F. A. (2024). Identifying Opportunities for Developing Nature-Based Sport Tourism to Improve Health in Papua: A Bibliometric Analysis of Research Over Ten Years. *Physical Education Theory and Methodology, 24*(5), 799-807. https://doi.org/10.17309/tmfv.2024.5.16

Received: 22.07.2024. Accepted: 09.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Review article

Mapping of Petanque Sports Research Trends for the period 2011-2024: A Bibliometric Analysis in the Scopus Database

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Accepted for Publication: September 19, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.17

Abstract

Objectives. This study aimed to conduct a bibliometric analysis of the trend of petanque sports from 2011 to 2024 in the Scopus database. The research focused on productivity assessment, publication type, journal ranking, frequency of publishing, number of citations, study area focus, keywords, and co-authorship.

Materials and methods. This study was carried out using a bibliometric method. The research stages comprised (1) searching for articles using the Boolean "Petanque" AND "petanque in sport", (2) inquiry with inclusion criteria of e-books, short reports, conferences, original articles, literature reviews in English, French, and Spanish from 2011 to 2024, (3) filtering 34 articles, (4) eliminating 19 articles, leaving 15 articles that were considered worthy, (5) re-filtering and producing the same number, namely 15 articles, and (6) deciding 15 final data articles. Data collection and analysis techniques used were Mendeley, VOSviewer, and Excel.

Results. In terms of productivity, 3 (20.00 %) documents were identified from 2011, 2021, and 2024; the most common type of document was original articles, with a total of 13 (86.67 %); the most journal rankings were in quartile 3 and 4 (30.00 %); the journals most frequently publishing research on petanque included the Journal of Physical Education and Sport, Ethnologie Francaise, Concurrences, and the International Journal of Human Movement and Sports Sciences, and Retos, each of which had 2 (13,00 %) documents; while the largest number of citations was from Pelana et al, with 26 citations. The majority of studies focused on physical, technical, and biomechanical aspects. The most commonly appearing keywords included performance, athlete, performance characteristic, sport, optimum group performance, and psychological training plan. Regarding collaboration, 14 researchers were found to be cooperating on the same research topic.

Conclusions. Petanque sports studies still require better research productivity and innovation to improve information and knowledge.

Keywords: bibliometric analysis, research trends, petanque sport, Scopus database.

Introduction

Petanque sports have emerged as competitive sports in Indonesia. This can be noticed in competition activities as petanque sports compete at regional and national levels. Petanque sports involve throwing iron and wood balls by the rules set (Soemardiawan & Yundarwati, 2024). Technically, the sport of petanque is divided into two categories: aiming and shooting techniques (Soemardiawan & Yundarwati, 2024). In this case, there are two types of throwing, namely shooting and pointing (Soemardiawan & Yundarwati, 2024). When we consider, petanque sports are dominating in body motions and physical activities such as physical, technical, and biomechanical aspects, and so forth. Other aspects such as psychological, aesthetic, and multidisciplinary considerations are required to provide information and generate new science regarding petanque sports.

Furthermore, as an academic, the authors were encouraged to perform further research on the sport of petanque through field investigations and document analysis in the form of relevant articles. Field observations show that the increase and excitement for the sport of

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petanque is positive, while document analysis in the form of relevant articles leads the author to conclude that articles about the sport of petanque are still not optimal. In this case, it is known that several articles that have been published in several databases are only limited to conducting analyses such as pointing motion analysis (Bustomi & Hidayah, 2020), petanque sports management survey (Hervi et al., 2021), development of a model for android-based petanque (Wulandari & Wibowo, 2022), and the effect of training with the obstacle method on pointing (Al bhaikhaqy, Risanggih et al., 2022). While some of these publications are prominent in the literature on training method analysis and testing, other studies, such as the mapping of research patterns in petanque sports studies using bibliometric analysis, have not received as much attention.

Recently, the publication style for manuscript writing has expanded beyond original research and literature reviews. Academics, on the other hand, are eager to do research using a bibliometric analysis model. In terms of data search and filtering, bibliometric research is equivalent to a literature review. The difference is that a literature review shows the essence and meaning of data, whereas bibliometrics reveals the bibliography of a specific field of study, including research productivity, collaboration patterns, often appearing keywords, and so on (Donthu et al., 2022)

Therefore, how does it relate to the sport of petanque? Undoubtedly, it is quite relevant. At first sight, it appears that research into petanque is already underway. However, is it only limited to discussing testing a training model and doing analysis and correlation? Of course, it is not the only instance when bibliometric analysis is required in the study of petanque. Given that prior studies have primarily focused on original research, academics have conducted very few systematic literature reviews and bibliometric analyses.

According to studies, bibliometric analysis is useful for synthesizing vast amounts of bibliographic data to interpret study performance and intellectual structure (Donthu et al., 2022). Knowledge in the field can be found objectively using bibliometric analysis, which describes field conditions as well as social patterns that support knowledge in the field and map knowledge gaps in the field (Lim, 2024). From another perspective, bibliometric analysis seeks to undertake objective assessments and reports on the productivity of research impacts (Lim, 2024), as well as to determine the scope and scope of research and biases that have not before been observed in research (Lim, 2024).

In this context, the authors perceive a gap in bibliometric research analysis in petanque sports, indicating that such analysis is required to give information and mapping of current research trends. As a result, the goal of this work is to map petanque sports trends from 2011 to 2024 using bibliometric analysis in the Scopus database. The author focuses on the Scopus Elsevier database since it is the most trusted source of bibliometric data for international research and also provides systematically examined knowledge about many fields (Tennant, 2020).

The purpose of this bibliometric analysis is to examine (1) productivity analysis, types of published articles, and journal rankings, (2) publication popularity by looking at the number of citations and the focus of petanque research studies, (3) keyword trends that frequently appear, and (4) co-authorship patterns. It is expected that this study will provide further information and insight, as well as increase publication output, particularly in petanque sports.

Materials and Methods

Study Participants and Organization

Bibliometrics is a problem-solving method employed in this study (Belfiore et al., 2020; Kussainova et al., 2023). This study stage included (1) a data search using the Scopus database with the Boolean analysis "Petanque" AND "Petanque in sport". The authors employ the Scopus database since the existing data considerations are complete and reliable after thorough screening (Bornmann et al., 2013). Stage (2) investigated data from 2011 to 2024, using research as inclusion criteria in the form of e-books, brief reports, conferences, and original articles in English, French, and Spanish. Articles that do not match the requirements are removed as exclusion criteria. In stage 3, the authors screen eligible data. In this stage, the authors obtain preliminary data from the Scopus database spanning 2011 to 2024, totaling 34 articles. Furthermore, in stage (4), the authors screen the articles, discarding 19 that do not meet the requirements and leaving 15 that do. In stage (5), the authors conduct a more thorough and rigorous re-screening, resulting in 15 articles that meet the criteria. In stage (6), the authors select 15 articles to proceed to the bibliometric analysis stage. To clarify, the authors present a diagram to establish the stages of data collection as follows:

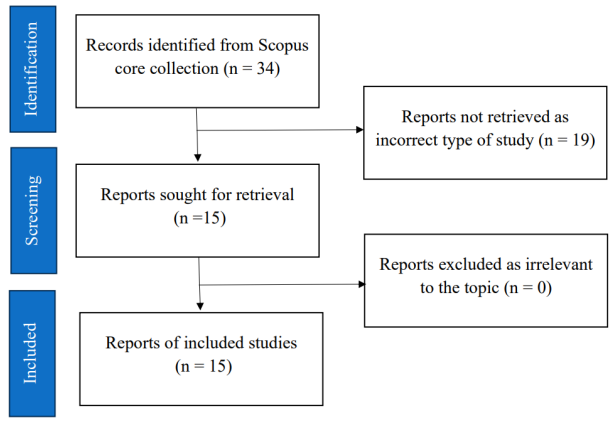

Fig. 1. Research flow diagram with inclusion and exclusion criteria

Data Analysis Technique

The data was gathered by document analysis with the Scopus database. The Mendeley desktop application, Vosviewer (Chen et al., 2022; Nugraha et al., 2023), and the Excel application to calculate the percentage are used to aid in the data analysis technique (Akhiruyanto et al., 2022; Yudhistira et al., 2023). The bibliometric analysis research focuses on (1) the analysis of productivity, publication type, ranking, and journals that frequently publish research on petanque; (2) analysis of popular articles based on the number of citations and focus of petanque research studies; (3) analysis of keyword trends that frequently appear in

petanque sports research; (4) analysis of co-authorship trends that frequently collaborate on petanque sports research; and (5) analysis of future difficulties and potential for petanque sports research.

Results

The results of the bibliometric analysis mapping are presented in tables and diagrams, namely (1) productivity analysis, publication type, journal ranking, (2) number of citations and focus of petanque sport studies, (3) analysis of frequently appearing keyword trends, and (4) analysis of co-authorship that frequently collaborates. To make things clear, the data results are presented as follows:

Table 1. Results of the analysis of Petanque Sports Research Productivity

No	Document	Amount	Percentage
1	2011	3	20.00
2	2012	0	0.00
3	2013	2	13.33
4	2014	0	0.00
5	2015	0	0.00
6	2016	1	6.67
7	2017	2	13.33
8	2018	0	0.00
9	2019	0	0.00
10	2020	0	0.00
11	2021	3	20.00
12	2022	1	6.67
13	2023	0	0.00
14	2024	3	20.00
Total amount		15	100

Fig. 2. Publication productivity diagram

Table 1 shows that the analysis of research productivity on petanque sports in 2011 was 3 (20.00 %), in 2012 it was 0 (0.00 %), in 2013 it was 2 (13.33 %), in 2014 it was 0 (0.00 %), in 2015 it was 0 (0.00 %), in 2016 it was 1 (6.67 %), in 2017 it was 2 (13.33 %), in 2018 it was 0 (0.00 %), in 2020 it was 0 (0.00 %), in 2021 it was 3 (20.00 %), in 2022 it was 1 (6.67 %), in 2023 it was 0 (0.00 %), and in 2024 it was 3 (20.00 %). The analysis findings show that publication productivity is still very low, as seen from the number of documents in the form of articles, which is only 3 documents at most. This is expected to continue in 2024, and it is hoped that the number of publications regarding petanque sports will rise. The following rising diagram presents it more clearly (fig. 2).

Table 2. Results of an analysis of publishing types, ranks, and journals that frequently publish articles on the sport of petanque

	No	Document	Amount	Percentage
Publication Type	1	Book	1	6.67
	2	Original article	13	86.67
	3	Literature review	1	6.67
	4	Proceedings	0	0.00
		Total amount	15	100
	No	**Quartile**	**Amount**	**Percentage**
Ranking journal	1	Quartile 1	2	20.00
	2	Quartile 2	2	20.00
	3	Quartile 3	3	30.00
	4	Quartile 4	3	30.00
		Total amount	10	100
	No	**Journal**	**Amount**	**Percentage**
Journals that frequently publish	1	Physical Education Theory and Methodology	1	6.67
	2	Journal of Physical Education and Sport	2	13.33
	3	Ethnologie Francaise	2	13.33
	4	Concurrences	2	13.33
	5	International Journal of Human Movement and Sports Sciences	2	13.33
	6	Retos	2	13.33
	7	New York State Folklife Reader: Diverse Voices	1	6.67
	8	Voices - Journal of New York Folklore	1	6.67
	9	Revista de Psicologia del Deporte	1	6.67
	10	Engineering Failure Analysis	1	6.67
		Total amount	15	100

According to Table 2, the bibliometric analysis of the type of book publishing is 1 (6.67 %), 13 (86.67 %) original articles, 1 (6.67 %) literature reviews, and 0 (0.00 %) proceedings. Therefore, it means that original articles are the most common type of publishing, with literature reviews, books, and proceedings remaining relatively rare. Although original articles continue to dominate, there is a need for more publications, particularly in the Scopus database.

According to Table 2, the bibliometric study of journal rankings shows that quartile 1 is 2 (20.00 %), quartile 2 is 2 (20.00 %), quartile 3 is 3 (30.00 %), and quartile 4 is 3.

In this case, the most dominant publications are in quartiles 3 and 4, although publication productivity in journals in quartiles 1 through 4 is still required, given that there is very little productivity discussing petanque sports, particularly in Scopus-indexed journals.

Based on Table 2, the bibliometric analysis of journals that often publish research on petanque are the journal Physical Education Theory and Methodology with 1 (6.67 %) article,

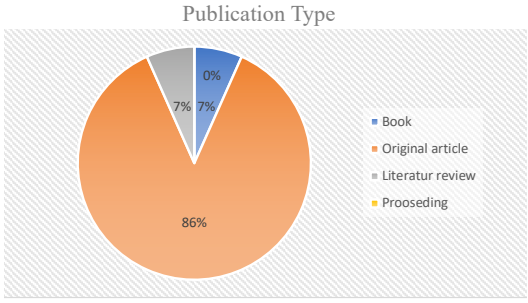

Fig. 3. Publication type diagram

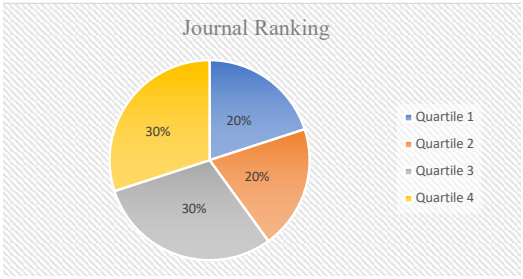

Fig. 4. Journal ranking diagram

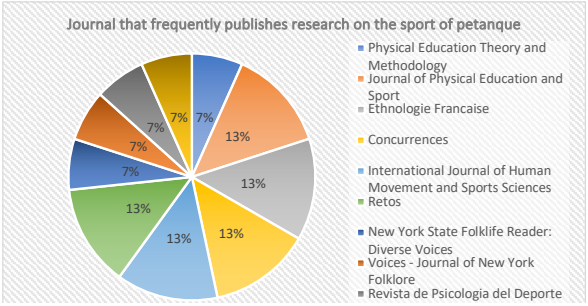

Fig. 5. Journal that frequently publishes research on the sport of petanque

Journal of Physical Education and Sport with 2 (13.33 %) articles, Ethnologie Francaise with 2 (13.33 %) articles, Concurrences with 2 (13.33 %) articles, International Journal of Human Movement and Sports Sciences with 2 (13.33 %) articles, Journal Retos with 2 (13.33 %) articles, New York State Folklife Reader: Diverse Voices with 1 (6.67 %) article, Voices - Journal of New York Folklore with 1 (6.67 %) article, Revista de Psicologia del Deporte with 1 (6.67 %) article, and Engineering Failure Analysis with 1 (6.67 %) article. Based on this study, these journals are still looking for more interesting papers concerning the sport of petanque. This is because there are still few publications regarding petanque sports, demonstrating that there is still room for them in these journals. To facilitate data interpretation, the authors present this analysis in the diagram below (fig. 3-5).

Based on Table 3, the authors examined 9 prominent articles with the most citations and concentrated on the field of study in petanque sports. The results of the analysis found that research from Pelana et al entitled "The Effect of Arms

Table 3. Analysis of 9 popular articles and focus of study areas

No	Article Title	Author's name	Number of Citations	The focus of the study area
1	The effect of arm length and endurance, and self-confidence on petanque shooting	Pelana et al. (2021)	26	Physical and psychological aspects of sports
2	The effect of an accuracy training program on petanque shooting results	Phytanza et al. (2022)	24	Skill aspects
3	The correlation between muscle endurance and arm length with petanque shooting accuracy	Setiakarnawijaya et al. (2021)	13	Physical and technical aspects
4	Mechanisms causing petanque ball explosions	Loser et al. (2011)	12	Engineering
5	The effect of self-talk on petanque shooting accuracy	Rizal et al. (2021)	5	Psychological and skill aspects
6	Kinematic motion analysis of petanque pointing and shooting techniques	Al Ardha et al. (2024)	3	Sports biomechanics
7	Android-based training program application for petanque sports	Hidayah et al. (2024)	2	Sports technology
8	Biomechanical analysis of throwing aura in petanque: a literature review study	Helmi et al. (2024)	1	Sports biomechanics
9	Finding optimal performance using a psychological training plan	Hernandez et al. (2011)	1	Sports psychology

Length and Endurance and Self-Confidence on Petanque Shooting" received 26 citations (Pelana et al., 2021). Second, research from Phytanza et al entitled "The Effect of Accuracy Training Programs on Petanque Shooting Results" received 24 citations (Phytanza et al., 2022). The third study from Setiakarnawijaya et al entitled "The Relationship between Muscle Endurance and Arm Length with Petanque Shooting Accuracy" received 13 citations (Setiakarnawijaya et al., 2021). Fourth, research from Loser et al entitled "Mechanism Causing Petanque Ball Explosion" received 12 citations (Loser et al., 2011). The fifth study is from Rizal et al entitled "The Effect of Self-Talk on Petanque Shooting Accuracy" which received 5 citations (Rizal et al., 2021). The sixth study comes from Al Ardha et al entitled "Kinematic motion analysis of petanque pointing and shooting techniques" which received 3 citations (Al Ardha et al., 2024). The seventh study is a study by Hidayah et al entitled "Android-Based Training Program Application for Petanque Sports" and received 2 citations (Hidayah et al., 2024). The eighth is a study by Helmi et al entitled "Biomechanical Analysis of Throwing Aura in Petanque: Literature Review Study" which received 1 citation (Helmi et al., 2024). The ninth is a study by Gonzalez et al entitled "Finding Optimal Performance with Psychological Training Plans" which received 1 citation (Hernandez & De Los Fayos Ruiz, 2011).

Furthermore, the primary focus of petanque research is on petanque sports performance as evaluated through the lens of physical aspects, skills, sports biomechanics, sports psychology, and engineering. The data indicate that research on the popularity of petanque is still limited, as indicated by the low number of citations. The majority of petanque studies focus on physical aspects, methods, sports biomechanics, and sports psychology. Although extensive research has been undertaken on the subject, further in-depth investigation is required. More fields of study, such as engineering and sports technology, are also required in petanque, and more sports sectors are still being developed to provide academics with knowledge and insight.

Table 4. Analysis of frequently appearing keyword trends

Label	Number of Keywords	Keywords
Cluster 1/Network visualization in red	3	Sport, optimum group performance, and physiological training plan
Cluster 2/Network visualization in green	3	Performance, athlete, and performance characteristics

Based on Table 4, the authors used the VOSviewer application to trace keywords that frequently appear in petanque sports studies, applying the minimum number of occurrences of a term, which is 1. This research revealed that 133 keywords met the criterion. The authors then performed a keyword selection in which if the keywords obtained were only 1, the authors deleted them to retain only the most keywords, which were performance, athlete, performance characteristic, sport, optimum group performance, and psychological training plan.

Based on Table 5, the authors analyzed to trace the co-authorship that frequently collaborates in petanque research with the VOSviewer application by using the minimal number of occurrences of a phrase, which is 1. The findings of this analysis revealed that 117 met the threshold, and the author found 14 co-authors who frequently perform research on petanque sports. They are Lourenco, Phytanza, Irawan, Widodo, Widiyono, Hadiatmo, Saleh, Sutopo, Burhaein, Indriawan, Azizah, Susanto, Dermrici, and Parmadi. To clarify, the VOSviewer analysis image shows the following:

Table 5. Trends in frequently collaborative co-authorship

Label	Number of Collaborations	Author
Cluster 1/ Network visualization in red	14	Lourenco, Phytanza, Irawan, Widodo, Widiyono, Hadiatmo, Saleh, Sutopo, Burhaein, Indriawan, Azizah, Susanto, Demrici, Parmadi

Discussion

Petanque is a relatively new competitive sport. This is common in regional and national competitions. This motivated the authors to do a bibliometric analysis study. Although the evolution of petanque sport through observation and observation demonstrates its presence in the world of sports, the analysis offered in this paper is still required to deepen understanding and information. Previous studies have primarily focused on correlational research, surveys, experiments, and designing a training program, but bibliometric analysis to map the trend of petanque sports research received little attention. As far as the authors are aware, no one has undertaken a bibliometric analysis of petanque sport. As a result, this is the first study to highlight the need for urgency in petanque sport research. To be more specific, the author did a bibliometric analysis with the main difficulties that will be addressed in the discussion section below as follows:

RQ1: How are the productivity, publication type, ranking, and journals that frequently publish petanque sports research developing between 2011 and 2024?

The outcomes of the highest research productivity on petanque are 3 (20.00 %) documents included in the Scopus database in 2011, 2021, and 2024. Furthermore, there were two (13.00 %) documents in 2013 and 2017, and only 1 (6.67 %) in 2016 and 2022. Aside from these years, there was no petanque research (0.00 %). This demonstrates that study on the sport of petanque is severely limited from year to year. Research productivity indicates that a topic is in high demand for research when the need for research is critical. As a result, research on the sport of petanque has not been in great demand to be included in the Scopus database. This permits the introduction of the sport of petanque to be described as suboptimal, or experts and academics participating in the sport of petanque have not given much thought to undertaking study on the sport of petanque. Although it may be claimed to be still going on in 2024, only three articles have been published in the Scopus database, which suggests that until the end of the year, research on petanque sports will be less significant than when one is

published in the Scopus database. As a result, academics must raise awareness to improve the output of petanque-related research that can be included in the Scopus database.

Furthermore, original articles are the most often published kind, accounting for 13 documents (86.67 %), followed by literature reviews and books, which account for 1 (6.67 %). However, proceedings have shown no interest in being published in Scopus proceedings. This demonstrates that there is still a lack of publishing in books, literature reviews, and proceedings, leaving many options for publication in these sources. Although the number of original articles has increased to 13 (86.67 %), productivity still needs to be improved. It is intriguing that secondary data analysis, such as literature reviews, is still underutilized in petanque sports studies, as is the author's research on bibliometric analysis, no one has been interested in analyzing it in more depth. To the authors' knowledge, this is the first time a bibliometric study of petanque sport has been published in a journal.

The analysis of the Scopus database journal ranking shows that research in petanque sports is frequently published in Scopus-indexed journals, with quartiles 1 and 2 totaling 2 (20.00 %) documents and quartiles 3 and 4 totaling 3 (30.00 %) documents. The smaller the quartile, the better, therefore it is expected that study on petanque sports will enter quartiles 1 and 2, where an in-depth examination is required to show problems both empirically and theoretically. The research goal must also be consistent with the problem to be considered for Scopus journal quartiles 1 and 2.

The journals that publish the most publications about pentanque are the Journal of Physical Education and Sport, Ethnologie Francaise, Concurrences, International Journal of Human Movement and Sports Sciences, and Retos, each with 2 (13.33 %) articles. This indicates that not many studies on petanque sports have been examined by other Scopus-indexed publications. The productivity of researchers who are nonetheless unenthusiastic about publishing their findings is a possible contributing factor. This productivity refers to the performance of an expert or academic who is motivated to provide knowledge and information to gain new scientific knowledge.

One of the factors influencing research output in petanque sports studies is that scientists are still not sufficiently focused on doing in-depth investigations and analyses. Furthermore, limited time and resources, as well as an intention to provide the most recent information, particularly in petanque sports, contribute to low research output in the field. This is consistent with prior research, which found that organizational characteristics and the researcher's conditions influence the determinants of a researcher's performance (Abramo et al., 2017). These factors have an impact on individual resources, available time, level of skill, and reputation, all of which are important in determining research productivity (Abramo et al., 2017). The decrease in productivity is due to researchers' continued focus on performing independent or solo research, which is frequently associated with delayed publication production. This is related to researchers' understanding of the value of research collaboration (Uddin et al., 2012). Specifically, research collaboration has an impact on enhancing article production, which can lead to more citations and publications (Bidault & Hildebrand, 2014; Ductor, 2016; Li et al., 2013). Naturally, the authors support the idea that research collaboration will result in a considerable increase in the number of articles published in petanque sports studies. A further in-depth examination will be provided in the RQ4 co-authorship analysis for petanque sports research collaboration.

RQ2: What are the most cited popular articles and the focus of research studies on petanque sports between 2011 and 2024?

The authors discovered nine documents with the most citations after conducting a bibliometric study to trace popular articles. The first rank that received the most citations was the research by Pelana et al with 26 citations (Pelana et al., 2021), the second was the research by Phytanza et al with 24 citations (Phytanza et al., 2022), the third most was the research by Setiakarnawijaya et al with 13 citations (Setiakarnawijaya et al., 2021), the fourth was the research by Loser et al with 12 citations (Loser et al., 2011), the fifth was the research by Rizal et al with 5 citations (Rizal et al., 2021), the sixth was the research by Al Ardha et al with 3 citations (Al Ardha et al., 2024), the seventh was the research by Hidayah et al with 2 citations (Hidayah et al., 2024), the eighth was the research by Helmi with 2 citations (Helmi et al., 2024), and the ninth was a study by Hernandez with 1 citation (Hernandez & DeLosFayosRuiz, 2011). However, Ronzano, Feschet, Wachsmann, et al.'s research has not earned any citations (Feschet, 2011, 2013b, 2013a, 2016; Wachsmann & Zacharie, 2017). The subject of study in petanque sports is primarily concerned with performance, including physical aspects, skill aspects, sports psychology aspects, and sports biomechanics, followed by sports technology and engineering.

As a result, articles that add to science and serve as references for other studies are distinguished by the number of citations, which facilitates the transmission of knowledge. The most often mentioned articles are 24 to 26, with the primary focus on physical elements such as arm strength and length, as well as technical features such as shooting accuracy and biomechanical analysis. This demonstrates that, on a theoretical level, petanque sports emphasize and focus on physical aspects, but it does not rule out the potential that psychological aspects, sports technology, and other research require improvement. Sports science evolves through the marriage of diverse sciences, resulting in a new paradigm.

Furthermore, the quantity of citations is frequently used to determine the study's popularity. The amount of studies that examine the topic and theme, or even make significant contributions to the execution of sports, demonstrates the study's appeal. According to past research, the number of times our scientific publications are mentioned indicates an overall scientific effect on the global academic community (Vieira & Gomes, 2010). The quantity of citations is thought to be associated with scientific quality and can be used to assess a researcher's academic achievement at an institution or department (Vieira & Gomes, 2010). Another study found that the popularity of articles with the most citations is influenced by three criteria (Tahamtan et al., 2016). The first factor includes the relevance of the article, the quality of the article, the interest and novelty of the participants,

the characteristics of the topic and focus of the study, the research method, the type of document, the research design, the characteristics of the description of the results and discussion, the images and attachments of the article used, the interesting title and abstract, the type of references used, the number and length of the article, the age of the article, the initial citation and the speed of citation, the visibility and ease of access of the article (Tahamtan et al., 2016). The second factor is the impact of the journal, the language of the journal, the scope of the journal, and the type of publication (Tahamtan et al., 2016). The third factor includes the number of authors, the track record of the authors, the academic ranking of the authors, self-citations, the collaboration of the authors in various studies, gender, age, race, the productivity of the author's publications, institutions and organizational features, as well as funding (Tahamtan et al., 2016).

Certainly, the authors are quite aware of the factors influencing the amount of citations listed above. However, in the study of petanque sports research, the authors' analysis discovered that citations have not been able to be numerous because, among other criteria, the number of publications on petanque sports, particularly in the Scopus database, is still not adequate. As a result, when it comes to impact and citations, it is undoubtedly required to boost the productivity of research published in Scopus-indexed journals. However, the lack of citations in petanque sports studies can be caused by a very basic thing: the urgency expressed in earlier studies cannot be considered to be particularly essential in real implementation.

RQ3: What is the trend of keywords that frequently appear in petanque sports research between 2011 and 2024?

The findings of bibliometric analysis using the VOSviewer application revealed a pattern of keywords that are frequently used in petanque sports studies. The authors applied the pattern of the minimum number of occurrences of a term is one, so the authors found 133 that meet the threshold. The authors then selected keywords by deleting irrelevant keywords and discovered keywords such as performance, athlete, performance characteristic, sport, optimum group performance, and psychological training plan.

In general, the word "sport" appears frequently, followed by the keywords performance, athlete and performance characteristics, optimal group performance, and physiological training plan. This suggests that the keywords that frequently occur are well-known in petanque sports studies. This keyword grouping is related to relevancy, demonstrating a correlation between several topics of study (Giannakos et al., 2020). To clarify, the authors depict it in the VOSviewer analysis graphic below as follows:

RQ4: What is the trend of co-authorship in petanque sports research collaboration between 2011 and 2024?

The results of bibliometric analysis using the VOSviewer application with co-authorship search to conduct research collaboration patterns in petanque sports studies revealed a very complex collaboration pattern in which authors who frequently conduct collaborative research on petanque sports are Lourenco, Phytanza, Irawan, Widodo, Widiyono, Hadiatmo, Saleh, Sutopo, Burhaein, Indriawan, Azizah, Susanto, Demrici, and Parmadi. For better understanding, the following is how the VOSviewer analysis visualizes it:

In general, collaboration trends seek to map issues that will subsequently be addressed and solutions sought, as well as identify organizations and academics that are working together on joint research projects. This is consistent with earlier research showing that research collaboration improves research productivity, which will be especially significant when authors work on international levels. On a global scale,

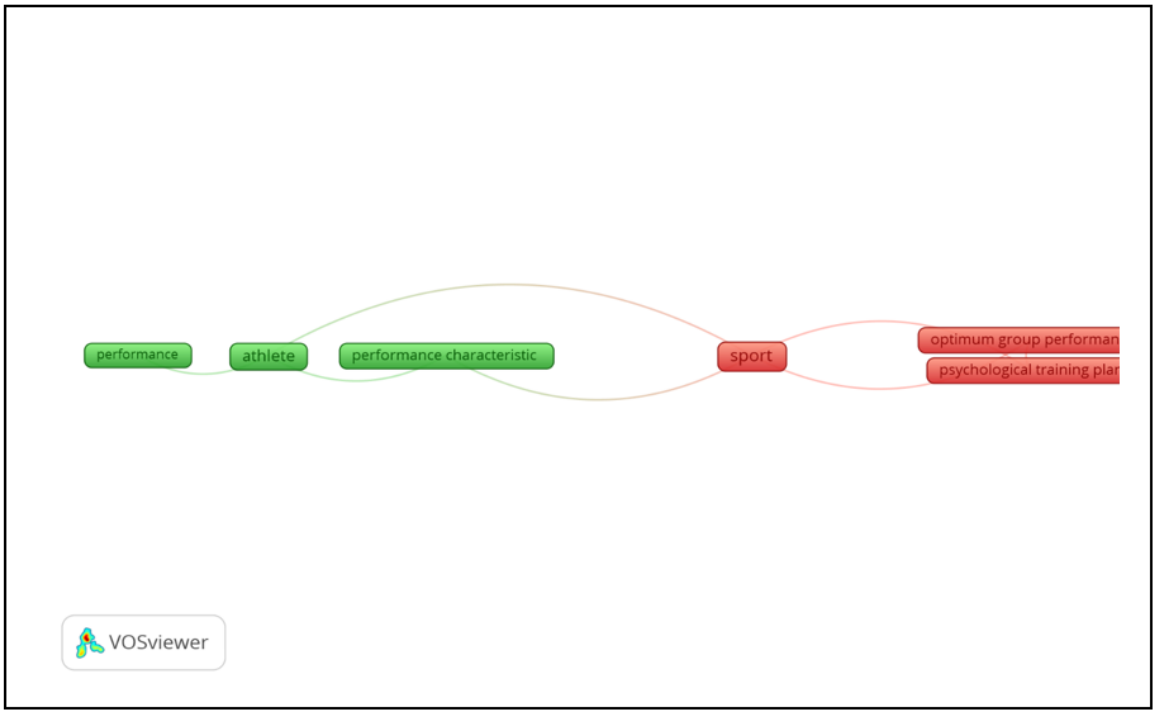

Fig. 6. Results of a network visualization study of commonly occurring keywords

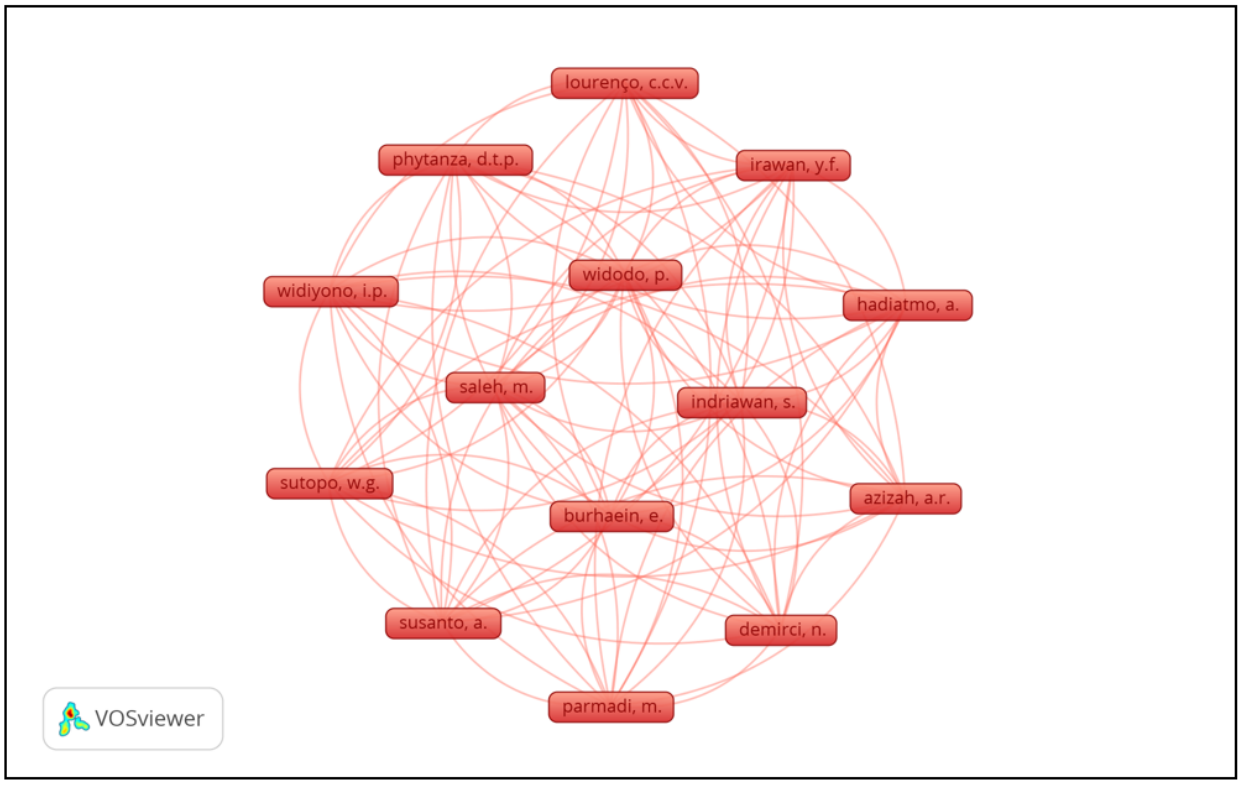

Fig. 7. Results of network visualization analysis of frequent collaboration co-authorship

diverse patterns of issue-solving will emerge with varying perspectives, resulting in variances in research and scientific advancement (Abramo et al., 2017). Adequate resources, motivation, and individual competency all influence publication and citation production, leading researchers to perform collaborative research more effectively (Abramo et al., 2017).

According to the authors, research collaboration allows single researchers to be aided by a team in managing research more successfully and efficiently. For example, a work can be separated into sections focusing on the introduction, technique, results and discussion, abstract and conclusion, editing, and submission. Teamwork is required to build a solid cooperative. The more problems are split to be answered, the more viewpoints there will be in the research, resulting in two to three subjects of study rather than just one.

In line with past studies, collaborative research tries to bridge and overcome the limitations of unresolved research (Abramo et al., 2017). In this context, the authors observe that there has been little collaborative research between international institutions on petanque sports; hence, the author only discovered regional collaborations. This study requires special attention to improve relations not only in petanque sports but also in many sectors of sports science studies so that future research can be even more dazzling and make valuable contributions.

RQ5: What are the problems and potentials in petanque sports research in the future?

This bibliometric analysis is useful for more than just identifying research trends and results. However, using bibliometric analysis, the authors can identify research issues that have not been and will be revealed. This problem has been outlined in the description above, but it is specifically explained in this section, namely about (1) research productivity. The productivity of special research that is included in the Scopus database is undoubtedly very low, which is possible because researchers have not been able to optimally reveal problems in detail to be used as rationalization material for problems. The problem in the study is the most significant component since it will make the research flow clear and easier to address by identifying the approach and how to perform it correctly. Previous studies in the study of petanque sports have described problems based on the perspective at the time of field observation, which is surely less accurate when employed as a research topic. This is undoubtedly one of the reasons why research on petanque has not been able to become part of the Scopus database to its full potential.

Aside from that, research output is influenced by individual competence, research collaboration, funding, and time flexibility. However, when it comes to competence, it is possible to read and reflect on a subject that will be researched using a high level of literacy. Research collaboration can be undertaken by establishing relationships and building a research team so that research efforts can be divided according to sub-field. Funding can also be sought, as many Scopus journals do not charge publication fees. Academics must prioritize their time and make time to write. Problem (2) is related to research collaboration, and while it has been done, it is important to note that international collaboration remains minimal. Research collaboration is critical to improving the quality and reach of foreign research.

Problem (3) is about citations. The huge amount of citations indicates that this research has an impact on knowledge

transmission. However, this is linked to productivity and research collaboration. The more petanque-related articles there are, the more relevant citations will be searched and used as references. In terms of collaboration, more authors advocate that other authors cite published research. Problem (4) concerns the scope of petanque research, which is not restricted to physical characteristics such as biomechanical analysis, arm length, and arm strength, but can also include technical studies, psychology, and the arts.

Future research on petanque sports should include more critical studies and relevant improvements, with the potential to have a real impact on the order of life in the sports community. Furthermore, research on petanque sports needs streaming and ongoing study to increase the productivity of article publications.

Conclusions

Based on the study's findings, the authors came to the following conclusions: the highest research productivity occurred in 2011, 2021, and 2024, totaling 3 documents (20.00 %); original articles accounted for 13 (86.67 %) of the published research, and the highest journal ranking was quartile 3 and quartile 4 (30.00 %); journals that frequently publish petanque research include the Journal of Physical Education and Sport, Ethnologie Francaise, Concurrences, International Journal of Human Movement and Sports Sciences, and Retos, each with 2 (13.00 %) documents, and the research by Pelana et al. had the highest number of citations, namely 26 citations. The focus of most studies is on physical, technical, and biomechanical aspects. Keywords that often appear are performance, athlete, performance characteristic, sport, optimum group performance, and psychological training plan. There are 14 collaborating researchers with the same research topic. The bibliometric analysis indicates that to give the most recent research advances, petanque sports research productivity needs to be optimized. To obtain trustworthy and high-caliber research, articles containing petanque sports studies can also be published in journals with a Scopus index or comparable. Even if this research can be finished, there are still a lot of unexplored things. For example, the analysis in this research is restricted to the Scopus database; the department, institution, and country of origin have not had their research output evaluated. Thus, to gather comprehensive data, additional research must focus on these aspects.

Acknowledgment

The authors would like to thank the Universitas Negeri Surabaya for enabling permission to conduct this research. The authors would then want to thank the team and co-authors for their assistance and support in completing this study effectively.

Conflict of interest

All authors declare no conflict of interest.

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Мапування тенденцій у галузі досліджень спортивних ігор з петанку за період 2011-2024 рр: Бібліометричний аналіз у наукометричній базі даних Scopus

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 11 с., 5 табл., 7 рис., 37 джерел.

Мета дослідження. Мета цього дослідження полягала у проведенні бібліометричного аналізу тенденцій у галузі спортивних ігор з петанку з 2011 по 2024 рр. у наукометричній базі даних Scopus. У дослідженні було зосереджено увагу на оцінці продуктивності, типі публікації, рейтингу журналу, частоті публікацій, кількості цитувань, фокусі галузі дослідження, ключових словах та співавторстві.

Матеріали та методи. Для проведення цього дослідження було застосовано бібліометричний метод. Етапи дослідження включали (1) пошук статей за допомогою застосування логічного типу даних «петанк» І «петанк у спорті», (2) запит з критеріями включення електронних книг, стислих звітів, конференцій, оригінальних статей, оглядів літератури англійською, французькою та іспанською мовами з 2011 по 2024 рік, (3) фільтрацію 34 статей, (4) виключення 19 статей, в результаті чого залишилося 15 статей, які були визнані доцільними, (5) повторну фільтрацію і отримання аналогічної кількості, а саме 15 статей, і (6) вибірку 15 статей, які увійшли до остаточного масиву даних. З метою збору та аналізу даних використовувалися програмні засоби Mendeley, VOSviewer та Excel.

Результати. З точки зору продуктивності, було виявлено 3 (20,00 %) документи з 2011, 2021 та 2024 років; найпоширенішим типом документів були оригінальні статті із загальною кількістю 13 (86,67 %); більшість рейтингів журналів були в 3 та 4 квартилях (30.00 %); серед журналів, які найчастіше публікували дослідження з петанку, представлені наступні видання: Journal of Physical Education and Sport, Ethnologie Francaise, Concurrences та International Journal of Human Movement and Sports Sciences, а також Retos, кожен з яких містив по 2 (13,00 %) документи; тоді як найбільша кількість цитувань належить публікаціям науковця Пелани та ін. (Pelana et al) – 26 цитувань. У більшості досліджень акцентовано увагу на фізичних, технічних та біомеханічних аспектах. Найчастіше зустрічалися такі ключові слова: результативність, спортсмен, характеристика результативності, спорт, оптимальна групова результативність та план психологічної підготовки. Щодо питань співпраці, було встановлено 14 дослідників, які займалися однаковою тематикою досліджень.

Висновки. Дослідження в галузі спортивних ігор з петанку й досі потребують покращення дослідницької продуктивності та інновацій задля підвищення рівня інформованості та знань.

Ключові слова: бібліометричний аналіз, тенденції досліджень, вид спорту петанк, наукометрична база даних Scopus.

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Cite this article as: Hafidz, A., Wiriawan, O., Nurhasan, Nurkholis, Nugraha, A. D., Purnomo, M., Pratama, R. S., & Yudhistira, D. (2024). Mapping of Petanque Sports Research Trends for the period 2011-2024: A Bibliometric Analysis in the Scopus Database. *Physical Education Theory and Methodology, 24*(5), 808-818. https://doi.org/10.17309/tmfv.2024.5.17

Received: 07.08.2024. Accepted: 19.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fizičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Review article

Serve Dynamics: Applying a Bibliometric Approach in the Kinetics and Kinematics Analysis for Flat and Topspin Serves in Tennis

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Accepted for Publication: September 9, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.18

Abstract

Objectives. The study aimed to completely examine the existing research on the investigation of kinetics and kinematics analysis for flat and topspin serves in tennis, with a special focus on improving performance and reducing injury risks for players.

Material and methods. In order to obtain a comprehensive understanding of the data, Scopus searched three variables in each record: (1) the author's name, (2) the journal name in which the paper was published, and (3) the total number of citations. Bibliometric analysis was used as part of the analysis. To gain a thorough and accurate comprehension, the data was analyzed and interpreted using a variety of data triangulation techniques. Building distance-based co-occurrence networks for bibliometric analysis and synthesis was carried out using the VOSviewer software. The classification and grouping of the terms derived from titles, abstracts, and keywords were carried out based on their degree of interconnectedness. The terms "Serve Dynamics in Tennis", "Kinetic Analysis in Tennis serve", "Kinematic Analysis in Tennis serve", and "Flat and Topspin serve in Tennis" are frequently used in the study, although their meanings are generally interpreted differently. The search yielded 125 papers and 2807 citations, which were used in the study conducted from 2001 to 2024.

Results. The study's findings revealed the primary authors, countries, and subject areas that contribute to a comprehensive understanding of research patterns, influential studies, authorship dynamics, thematic clusters, and international collaborations in the analysis of the kinetics and kinematics for flat and topspin serves in tennis.

Conclusions. The study concludes by consolidating current information and identifying potential avenues for broadening the interdisciplinary scope of tennis serve research.

Keywords: biomechanics, tennis, kinetics and kinematics analysis, flat serve, topspin serve, serve dynamics, bibliometric analysis, and VOSviewer.

Introduction

The tennis serve is one of the most difficult tactics to master, despite the fact that the player appears to have complete control and advancement over it. It is tough to master the most perfect technique because the upper and lower extremities movements require sophisticated coordination (Carboch et. al., 2023). Accordingly, the tennis serve is both the most crucial and the most difficult stroke to perfect. It comes in three main types: flat, topspin, and slice (Mourtzios et al., 2022). The flat kick (topspin) and slice (sidespin) serve to use comparable upper-body temporal as well as kinematic characteristics to generate high translational ball velocities (Sheets et al., 2011). The flat serve may be the fastest, but the topspin serve is frequently the most consistent. Although speed production is essential for flat serve efficiency, the dimensions and boundaries of the service box must be such that an accuracy component is retained (Whiteside et al., 2014).

One of the most crucial aspects of contemporary tennis competition is a superb serve. The flat serve is usually the first serve of a highly skilled tennis player, while the slice or topspin serve is the second serve (Groppel & Roetert, 1992). To be successful as a professional tennis player, one must have a variety of serves, combining flat and topspin

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(Giampaolo & Levey, 2013). Both the serve and the return are crucial strokes in tennis, and as a player advances in the professional ranks, so does the difficulty of these two shots (Avilés et al., 2019; Chang & Qiu, 2022).

Based on the racket face position and velocity vector with respect to the ball at impact, three main types of tennis serves are typically recognized. There's the flat approach, which boosts speed while reducing spin; the slice method, which puts an emphasis on sidespin; and the twist method, which uses both topspin and sidespin (Connolly, 2020; Sheets et. al., 2011) also known as kick serve (Sakurai et.al., 2013; Cross, 2011). After discovering that different tennis serves to require different technique execution, researchers examined the kinematics of the body's segments, the tennis racket, as well as the tennis ball throw (Sheets et. al., 2011; Mourtzios et. al., 2022). Scholars and practitioners alike have been captivated by the dynamics of these services, driven by a desire to comprehend the intricate interplay between kinetics and kinematics that determines their effectiveness. When serving flat, the front part of the racket's velocity is important; when serving slicing, the lateral part of the racket's velocity is more important than the forward part; and when serving twisting, the vertical part of the racket's velocity is more important than the forward and lateral parts (Reid et al., 2007). Serving with a lot of speed usually gives you the upper hand in tennis (Fett et al., 2020).

Biomechanical research has helped to identify the essential kinetic and kinematic components of racquet velocity in the first serve. Many studies have been undertaken to understand these kinematics (Lambrich & Muehlbauer, 2023; Ramasamy et al., 2023; Mishra, 2023; Ramasamy, 2021; Ibrahim, 2020). Factors such as the racquet's velocity and direction, the ball's height at stroke, the racket's overall weight, the racket's angle at impact, and the ball's speed along with direction at this instant are among the most important elements in a serve. The biomechanics study of tennis serves has evolved significantly with the development of motion capture technology and high-speed cameras, which enable exact analysis and measurement of player motions (Abrams et. al., 2016). Researchers have used a variety of methods, including 3D motion analysis, force plates, and wearable sensors, to collect data on joint angles, velocities, accelerations, and forces during serves. These data-driven approaches have not only enhanced the comprehension of serve mechanics but also permitted comparisons between different serving methodologies and player characteristics.

Bibliometric analysis is an effective approach for visualizing the intellectual landscape of a study topic, providing insights into the evolution of thoughts, crucial contributions, and emerging trends (Hallinger & Nguyen, 2020). A bibliometric approach to tennis serves allows for the discovery of major studies, influential scholars, and promising research pathways. By synthesizing and synthesizing findings from a variety of sources (Martín-García et. al., 2022).

This study seeks to identify key patterns and trends that characterize the current level of research on service dynamics. The purpose of this study is to investigate and analyze the dynamics of tennis serve approaches, notably flat serves and topspin serves, utilizing a bibliometric approach to kinetics and kinematics. The research will help us understand the biomechanical principles that underlie different kinds of tennis serves, which could lead to new insights that help us play better and avoid injuries. The paper will map out the existing literature landscape using bibliometric methods, identifying key trends, gaps, and areas ripe for future research in the field of tennis biomechanics. Such insights are critical for coaches, athletes, and sports scientists looking to improve training tactics and technical abilities in competitive tennis. Based on the aforementioned need for the study, the following research questions are generated:

Q1. What is the current research landscape for analyzing kinetics and kinematics in tennis flat and topspin serves?
Q2. What are the key biomechanical characteristics investigated for flat and topspin serves?
Q3. How has research on service dynamics developed over time in terms of techniques and technical advancements?
Q4. What are the most cited papers and authors in the field of tennis serve biomechanics?
Q5. What are the current gaps and emerging research directions in tennis serve biomechanics?

By combining existing literature and academic works on this topic, the study attempts to give a comprehensive review and critical analysis of the techniques, conclusions, and trends in tennis to serve biomechanics research. Its specific goal is to uncover relevant studies, notable academics, and prominent journals that contribute to a better knowledge of how flat and topspin serves are completed and optimized mechanically. The purpose of this bibliometric analysis is to provide insights into the current state of research, identify areas of agreement or disagreement, and recommend routes for future research aimed at improving performance and minimizing injury risk in tennis serve mechanics.

Materials and Methods

There are several approaches to doing systematic reviews, one of which is the framework-based review (Robinson et al., 2011), meta-analyses (Zhang et al., 2022), and bibliometric reviews (Li et al., 2023). This also refers to the breadth and comprehensiveness with which scholars review and analyze data. One unique feature of bibliometric analysis is the user-friendly interface for accessing the co-citation network.

Citation analysis is commonly utilized in bibliometrics to conduct basic research (Van Eck et al., 2013). Depending on the unit of analysis, different aspects of a study issue might be examined. Keywords, institutions, organizations, countries, journals, and publications are common research analysis units. Citation analysis presupposes that writers reference or discuss articles that they believe are significant (Moed, 2006). By analyzing the interdependence of later publications, author co-citation analysis can shed light on the intellectual structure of multiple fields, including science and others (Van Eck & Waltman, 2017). The steps in generating bibliometric data involve choosing a database, analyzing bibliographic information, and making them more accessible. Then, it is necessary to select the program and decide how to exhibit the data.

According to the study, researchers should prioritize the most significant papers for their investigation on "Serve Dynamics: A Bibliometric Exploration of Kinetics

and Kinematics Analysis in Flat Serve and Topspin Serve in Tennis". The Scopus database was chosen as a reliable source for gathering citation data due to the necessity of understanding the role of biomechanics in tennis play, as well as kinetics and kinematics analysis. Understanding the principles and importance of kinetics and kinematics analysis in tennis is one of the key objectives. This is critical since the words "Kinetics and Kinematics analysis", "Tennis Serves", and "tennis performance" are often used but can be interpreted differently according to the circumstances. The search yielded 137 papers and 2807 citations, which were used in the study conducted between 2001 and 2024. This huge dataset provides a solid foundation for examining the significance of kinetics and kinematics analysis in tennis serve and performance, as well as understanding how flat and topspin serves are executed and optimized globally. Figure 1 depicts the flow of information during various stages of a systemic screening process.

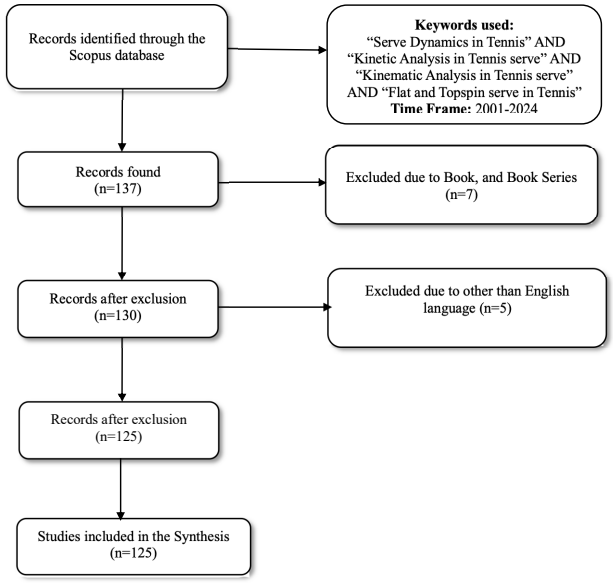

Fig. 1. Visual representation of the flow of information through the different phases of a systemic screening process

Figure 1 depicts the PRISMA paradigm, which gives an organized and clear picture of the screening process used to find relevant studies. Initially, 137 documents were identified through the Scopus database using particular keywords linked to "Serve Dynamics in Tennis", "Kinetic Analysis in Tennis serve", "Kinematic Analysis in Tennis serve", and "Flat and Topspin serve in Tennis" throughout the span of 2000-2024. Seven records were omitted from this original group because they were published as books or book series. After applying the exclusion criteria, 130 records remained. 5 records were then eliminated because they were in languages other than English, leaving a total of 125 records. Finally, 125 studies were included in the synthesis, fitting the criteria for relevance and providing the foundation for analysis. Overall, the PRISMA model shows how the original pool of records is gradually filtered to choose studies for synthesis and analysis, ensuring a methodical and thorough approach to the literature review.

Scopus searched three variables in each record: (1) the author's name, (2) the journal name in which the paper was published, and (3) the total number of citations. Bibliometric analysis was used as part of the analysis. To gain a thorough and accurate understanding, the data was analyzed and interpreted using a variety of data triangulation techniques. Bibliometric analysis and synthesis were conducted by creating distance-based co-occurrence maps using the VOSviewer software. Classification and grouping of the terms received from titles, abstracts, and keywords were done based on their degree of interconnectedness.

Table 1. Inclusion and Exclusion Criteria

Criterion	Inclusion	Exclusion
Keywords	Records conferring the role of Kinetics and Kinematics analysis in tennis serve and performance and the understanding of how flat and topspin serves are executed and optimized	Records excluded in which variables have no relation.
Type of Literature	Journals, Review Articles	Book series, book, chapter in book,
Language	English	Other than English
Time frame	Concerning 2001-2024	<2001
Paper Stage	Final stage	Excluded that are on the running stage

Supplementary Table 1 summarizes the criteria used to choose papers for the study Exploration of Kinetics and Kinematics Analysis in Flat and Topspin Serve in Tennis. The "Criterion" column's inclusion standards state that records must demonstrate the role of Kinetics and Kinematics analysis in tennis serve and performance, as well as a grasp of how flat and topspin serves are executed and maximized. This guarantees that only papers directly related to the study topic are included. In contrast, the exclusion criteria state that records are removed if the variables are unrelated to the issue. This technique helps to eliminate extraneous papers that may not provide any useful insights into the research. Journals and review articles are among the types of literature evaluated, as they are known for their thorough and focused attention to specific concerns. Book series, individual books, and book chapters must be excluded since they may lack the depth or relevance needed for the study.

The analysis only includes papers written in English because the researchers are fluent in the language. Papers produced in languages other than English are excluded because they may contain language hurdles. The study spans 2001 to 2024, allowing for the inclusion of current research while also capturing a large volume of relevant literature. Papers published before 2001 are excluded because they

may not be relevant to current trends or discoveries in the field. Finally, papers at the final stage are included, whilst those in the running stage are excluded. This ensures that only research completed and evaluated by specialists is considered for the study.

Citation Analysis

The study titled "Serve Dynamics: Applying a Bibliometric Approach in the Kinetics and Kinematics Analysis for Flat and Topspin Serves in Tennis" provides comprehensive research data on various aspects of the field. This includes the annual publication count, the most frequently cited documents, notable authors, influential journals, and leading countries in the domain.

Table 2 provides a concise overview of citations, specifically highlighting the 15 publications that have been cited most frequently on the given subject. The material presented above is the basis for a comprehensive examination of the study of Kinetics and Kinematics in the Flat serve and Topspin Serve in Tennis on a global scale.

The table presents the articles with the highest number of citations in the field of tennis serve analysis, emphasizing their noteworthy contributions to this area of research. With 200 citations, the study on anticipatory skills by Farrow and Abernethy (2002) is the most mentioned. A study on the loading of the upper limbs during tennis serves was carried out by Elliott et al. (2003) and garnered 198 citations. The study's findings were published in the science journal Sports Medicine. An extensive 107-citation study of Grand Slam Matchplay's features was carried out by Reid et al. (2016). The Journal of Sports Sciences published this work. The 2009 study by Gillet et al. received 103 citations in the Journal of Strength and Conditioning Research for its examination of elite athletes' advanced serving and returning techniques. In their study, Farrow and Reid (2012) investigated the impact of scenario probability knowledge on anticipatory competence. Their research has been cited 101 times. Additional noteworthy research includes the study conducted by Hornery et al. (2007) which examined physiological profiles in tennis and has received 92 citations. Another significant study by Gordon and Dapena (2006) investigated

Table 2. Citation Analysis of Different Authors

No.	Most cited papers and Authors	Source/journal	Total Citations
1.	Can anticipatory skills be learned through implicit video-based perceptual training? (Farrow and Abernethy, 2002)	Journal of Sports Sciences	200
2.	Technique effects on upper limb loading in the tennis serve (Elliott et al., 2003)	Journal of Science and Medicine in Sport	198
3.	Matchplay characteristics of Grand Slam tennis: implications for training and conditioning (Reid et al., 2016)	Journal of Sports Sciences	107
4.	A notational analysis of elite tennis serves and serve-return strategies on the slow surface (Gillet et al., 2009)	Journal of Strength and Conditioning Research	103
5.	The contribution of situational probability information to anticipatory skill (Farrow & Reid, 2012)	Journal of Science and Medicine in Sport	101
6.	An integrated physiological and performance profile of professional tennis (Hornery et al., 2007)	British Journal of Sports Medicine	92
7.	Contributions of joint rotations to racquet speed in the tennis serve (Gordon and Dapena, 2006)	Journal of Sports Sciences	75
8.	Lower-limb coordination and shoulder joint mechanics in the tennis serve (Reid et al., 2008)	Medicine and Science in Sports and Exercise	68
9.	Upper Limb Biomechanics During the Volleyball Serve and Spike (Reeser et al., 2010)	Sports Health	67
10.	Tactical determinants of the setting zone in elite men's volleyball (Afonso et al., 2012)	Journal of Sports Science and Medicine	67
11.	Recognising the style of spatially exaggerated tennis serves (Pollick et al., 2001)	Sustainability (Switzerland)	67
12.	Comparing the pre- and post-impact ball and racquet kinematics of elite tennis players' first and second serves: A preliminary study (Chow et al., 2003)	Journal of Sports Sciences	64
13.	Energy flow analysis during the tennis serve: Comparison between injured and non-insured tennis players (Martin et al., 2014)	American Journal of Sports Medicine	59
14.	Caffeine, carbohydrate, and cooling use during prolonged simulated tennis (Hornery et al., 2007)	International journal of sports physiology and performance	59
15.	Shoulder joint loading in the high performance flat and kick tennis serves (Reid et al., 2007)	British Journal of Sports Medicine	57

the impact of joint rotations on racquet speed and has been cited 75 times. The list also encompasses studies on shoulder mechanics, lower-limb coordination, and comparisons of serve kinematics, demonstrating a wide-ranging fascination with diverse biomechanical and physiological facets of tennis serves. The presence of prestigious journals such as the American Journal of Sports Medicine, Medicine and Science in Sports and Exercise, and the British Journal of Sports Medicine demonstrates that this field of study is very interdisciplinary.

Yearly Publication

Figure 2 depicts the cumulative count of articles on the examination of Kinetics and Kinematics in Flat Serve and Topspin Serve in Tennis that have been included in the Scopus database from 2015 to 2024.

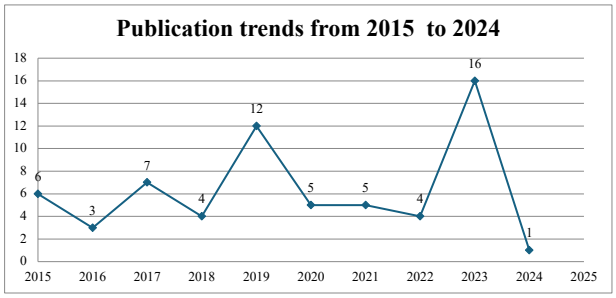

Fig. 2. The number of total publications on Kinetics and Kinematics analysis in Flat Serve and Topspin Serve in Tennis indexed in Scopus 2015-2024

The data on annual publications from 2015 to 2024 demonstrates varying levels of interest and research activity in the study of kinetics and kinematics analysis of flat and topspin serves in tennis. The initial research output was limited, consisting of only 6 papers in 2015, which saw a decrease to 3 in 2016. There was a substantial increase in publications in 2017, with a total of 7 papers. However, there was a notable decrease in the following years, with just 4 publications in 2018. The research activity had a gradual rise and then stabilization in 2019, with the number of publications varying by 12 in 2019. From 2020 to 2022, there was a consistent decrement, such as 5 publications in 2020, 5 publications in 2021, and 4 publications in 2022. Following this, there was a subsequent surge to 16 publications in 2023. Nevertheless, in 2024 there was a significant decrease to only one publication, suggesting a possible recent reduction in research productivity or a delay in submitting data for the present year. In general, the pattern shows intermittent increases and decreases, indicating fluctuating levels of research interest and funding availability in this specific field across time.

Top Authors

Figure 3 shows a list of authors and the number of papers they have written on kinetics and kinematics analysis in flat and topspin serves in tennis. Reid M. leads the contributions with 33 documents, demonstrating a strong influence and prolific productivity in this research area. Elliott B. has 25 documents, followed by Farrow D., who has 11. Both are important contributors. Rogowski I. and Chèze L. have created seven and five documents, respectively, demonstrating active involvement in the field. Several authors, notably Mujika I., Hornery D.J., Campbell A., and Gillet B. have four documents, while O'Sullivan P. and Dumas R. have three. Begon M., Buszard T., and Pinder R. have all submitted two documents. This distribution illustrates a core group of scholars with varied degrees of impact and output in the study of tennis serve mechanics.

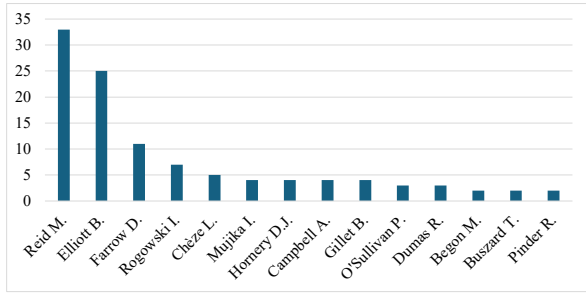

Fig. 3. Top authors and the number of documents they have published in the field

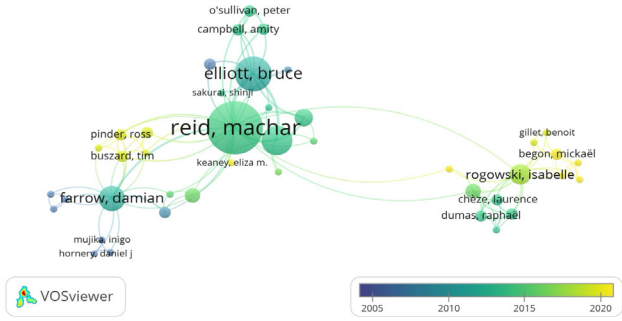

Fig. 4. Co-authorship between Authors

The first analysis of co-citations looked at the author's network of Scopus citations. In author co-citation analysis, the choice of which authors to map is the most important decision. A field's or topic's intellectual structure can be mapped using co-citation analysis, as mentioned above. Consequently, Scopus uses author co-citation analysis to discover the intellectual structure of authors, who are significant contributors who produce a collection of papers connected to a subject.

The bibliometric network visualization depicts the relationships and partnerships between authors working on the kinetics and kinematics of flat and topspin serves in tennis. Reid, Machar, and Elliott, Bruce are central people with notable publications and substantial collaborations, as seen by their enormous rings and numerous connecting lines. The network shows different groupings of regular collaborators, including Rogowski, Isabelle, and Farrow, Damian. Temporal patterns reveal that authors such as Rogowski and Gillet, Benoit, have been more active recently, although Farrow and Mujika, Inigo, have previously contributed. The connection is underscored by thick lines

connecting closely collaborating authors, particularly Reid and Elliott. Recent papers and developing network ties highlight emerging researchers, like Begon, Mickaël, and Chèze, Laurence. This image effectively illustrates the primary contributors, their cooperation networks, and the evolution of research over time in this specialized sector.

Subject area Analysis

Figure 5 depicts the distribution of research publications across disciplines. Medicine accounts for 38 % of the papers, demonstrating a strong emphasis on medical research within the studied body of work. Health Professions follow closely after with 32 %, indicating a strong concentration on health-related occupations. Engineering and computer science both contribute to 7 % of the texts, indicating moderate contributions from these technological fields. Social Science and Psychology account for 5 % and 4 %, respectively, reflecting their importance in the larger study landscape. Neuroscience and Arts & Humanities have the smallest shares, accounting for 4 % and 3 % of articles, respectively. This distribution emphasizes the overwhelming significance of medical and health professions research, with diverse but minor contributions from other disciplines.

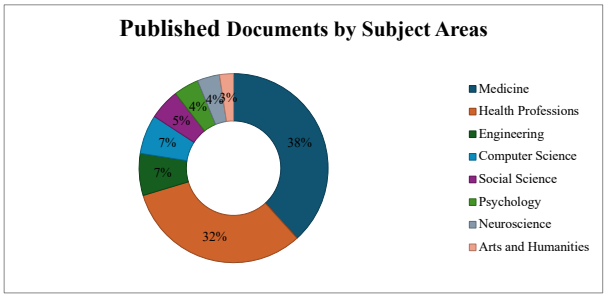

Fig. 5. Distribution of documentation in various subject areas

Country Analysis

Figure 6 depicts the top countries and regions in research collaboration linked to kinetics and kinematics analysis in flat and topspin tennis serves from 2001 to 2024. The figures presented show the number of publications from various nations, with Australia having the most at 39, followed by France with 22. The United States and China are also significant, with 20 and 18 publications each. Germany has seven publications, followed by Japan, which has five. The United Kingdom and Switzerland have four publications each, while India and Thailand have two. This distribution implies various degrees of research production or importance in publications across these countries, with Australia and France at the top.

The bibliometric network visualization depicts international links and collaborations in the subject of kinetics and kinematics analysis of flat and topspin serves in tennis. The United States, Australia, and France are key players with big publications and extensive partnerships, as seen by their large rings and numerous connecting lines. The network identifies various groupings of regular collaborators, including China, Germany, and Japan.

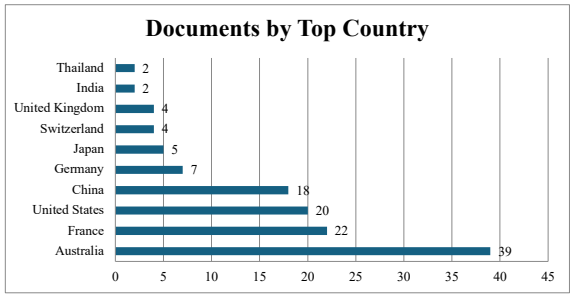

Fig. 6. Top Countries and Regions in Research on Documents

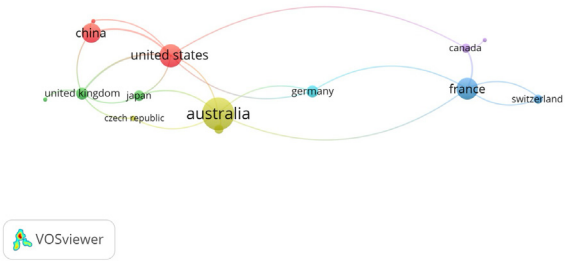

Fig. 7. Cluster Diagram depicting Top Countries indicating a significant contribution to research

Temporal trends reveal that countries like Switzerland and the United Kingdom have been increasingly active recently, whereas India and Thailand make modest contributions.

Co-Occurrence of Keywords

The visualization for the bibliometric study "Serve Dynamics: A Bibliometric Exploration of Kinetics and Kinematics Analysis in Flat Serve and Topspin Serve in Tennis" identifies major thematic clusters and correlations in the academic literature. Central concepts like "tennis," "humans," and "sports" dominate the graphic, suggesting their popularity and significance in the field. The term "tennis serve" appears prominently, highlighting the research's major focus. The visualization shows several distinct clusters: one centered on "sports," "average speed," "flat serve," and "court," which emphasizes the physical and performance aspects of tennis serves; another cluster includes terms like "mechanical

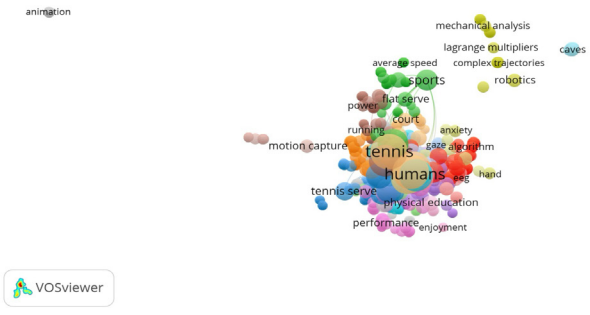

Fig. 8. Co-occurrence of Keywords

analysis," "LaGrange multipliers," and "complex trajectories," reflecting the biomechanical and analytical approaches used in the study of serve dynamics. There are also smaller clusters connected to psychological and physiological factors, as demonstrated by phrases such as "anxiety," "gaze," and "eeg," as well as technology and methodology, seen in terms such as "motion capture" and "algorithm." This extensive network map captures the diverse nature of research on tennis serve dynamics, including performance analysis, biomechanics, psychological aspects, and technological techniques.

Findings and Discussion

The results of the bibliometric investigation of kinetics and kinematics analysis in flat and topspin serves in tennis provide important insights into the evolution and current landscape of research in this specialized topic. First, an examination of highly cited papers reveals key contributions that shaped the debate. Farrow and Abernethy's (2002) study of anticipatory skills received 200 citations, highlighting the importance of cognitive factors in service dynamics. Elliott et al. (2003) follow closely, emphasizing upper limb loading during serves, which is critical for understanding biomechanical stresses in tennis. Reid et al. (2016) and Gillet et al. (2009) provide insights into Matchplay features and elite strategies, respectively, adding to the research on competitive tennis dynamics.

Second, considering the publishing patterns from 2001 to 2024 demonstrates fluctuations in research efforts. Early years witnessed modest output, with irregular peaks such as in 2003, indicating intermittent surges in interest, maybe due to technical developments or sporting events. Significant recent growth in 2019 and 2023 contrasts with a fall in 2024, indicating potential adjustments in financing or research priorities in the subject. Third, the distribution of author contributions highlights prominent figures in research. Reid M. emerges as a prolific researcher, with 33 documents demonstrating significant influence and ongoing interaction. Elliott B. and Farrow D., with 25 and 11 documents respectively, also play important roles, proving their long-term contributions to service dynamics research. The collaborative network analysis emphasizes major figures like Reid and Elliott, exhibiting dense linkages suggestive of long-term cooperation and cooperative research pursuits.

Furthermore, the distribution across topic areas demonstrates the interdisciplinary character of research, with medicine and health professions dominating, highlighting the biomechanical and physiological foundations of serve dynamics. Engineering and computer science also make contributions, demonstrating technological advances in motion analysis and simulation approaches. Geographically, Australia and France lead in research production, with significant contributions from the United States, China, and other countries, demonstrating worldwide interest and collaboration in tennis serve kinetics and kinematics study. Overall, this bibliometric analysis gives a comprehensive view of the research environment, highlighting significant authors, topic clusters, and global collaborations that shape our understanding of tennis serve dynamics. The findings highlight the diverse approach – from cognitive and biomechanical studies to technological advancements – which jointly increase knowledge and practice in sports science and performance analysis.

Conclusion

Finally, the bibliometric investigation into kinetics and kinematics analysis in flat and topspin serves in tennis reveals numerous noteworthy discoveries. To begin, it lists seminal contributions to the subject, such as Farrow and Abernethy's work on anticipatory skills and Elliott et al.'s research on upper limb loads, both of which have had a substantial impact on research paths and have received numerous citations. The shifting pattern of annual publications highlights variable research interest and funding availability throughout time, displaying peaks and valleys in research production. Authors such as Reid, Elliott, and Farrow emerge as key personalities, with significant contributions and large collaboration networks. The prevalence of medical and health-related fields in published publications indicates a strong emphasis on the biomechanical and physiological elements of tennis serves. Geographically, Australia and France lead in research output, with major collaborations seen amongst countries such as the United States, China, and Germany. Future research should investigate broadening interdisciplinary cooperation, incorporating technological improvements, and investigating underrepresented topics including psychological aspects and novel methodological approaches. By addressing these features, researchers might further improve our understanding of tennis serve mechanics, perhaps improving player performance and injury prevention techniques.

However, it is critical to recognize some limitations in this study. Citation counts may be biased towards older, more established works, perhaps disregarding recent advances or developing trends. The bibliometric study is also largely concerned with quantitative indicators, which may not fully represent the qualitative impact or innovative contributions of certain books. Furthermore, the geographical concentration on individual countries may leave out significant findings from locations with burgeoning tennis research communities.

This research has consequences beyond academia, including practical applications in sports science and training. Researchers may enhance the subject of serve dynamics in tennis by encouraging ongoing collaboration and innovation, providing players, coaches, and sports enthusiasts with better insights into performance optimization and injury prevention techniques.

Acknowledgment

I would like to express my sincere gratitude to my guide/supervisor for their invaluable support, guidance, and mentorship throughout the course of this study. Their expertise and encouragement were instrumental in shaping the direction of the research and overcoming various challenges along the way. Additionally, I am deeply thankful to my friends and family for their unwavering support, understanding, and encouragement throughout this journey. Their constant encouragement and belief in my abilities have been a source of strength and motivation, enabling me to persevere through the ups and downs of the research process.

Conflict of interest

All authors declare no conflict of interest.

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Динаміка подачі: Застосування бібліометричного методу в контексті аналізу кінетики та кінематики виконання техніки подач "flat" та "topspin" у тенісі

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 10 с., 2 табл., 8 рис., 41 джерело.

Мета дослідження. Мета дослідження полягала в комплексному вивченні існуючих наукових праць з аналізу кінетики та кінематики виконання техніки подач "flat" (удар з невеликим бічним обертанням або плоска подача) та "topspin" (удар із сильним верхнім обертанням або топ-спін) у тенісі, з особливим акцентом на покращенні результативності та зниженні ризику травмування гравців.

Матеріал та методи. Задля отримання цілісного розуміння даних, у наукометричній базі Scopus здійснювався пошук за трьома змінними в кожному записі: (1) ім'я автора, (2) назва журналу, в якому було опубліковано статтю, та (3) загальна кількість цитувань. Бібліометричний аналіз було застосовано як складову аналізу. З метою отримання ґрунтовного і точного осмислення інформації, отримані результати були проаналізовані та інтерпретовані з використанням різноманітних методів тріангуляції даних. Побудова дистанційних мереж суміжностей для проведення бібліометричного аналізу та синтезу здійснювалася за допомогою програмного забезпечення VOSviewer. Класифікація та групування термінів, отриманих з назв, анотацій та ключових слів, проводилися на основі ступеня їх взаємозв'язку. Терміни «Динаміка подачі в тенісі», «Кінетичний аналіз подачі в тенісі», «Кінематичний аналіз подачі в тенісі», «Плоска і топспін подача в тенісі» часто використовуються в дослідженні, однак їх значення, як правило, трактуються по-різному. За результатами пошуку було виявлено 125 робіт і 2807 цитувань, які використовувалися в дослідженні, проведеному в період з 2001 по 2024 рік.

Результати. Отримані результати дослідження визначили провідних науковців, країни та предметні області, які сприяють всебічному розумінню дослідницьких моделей, найбільш вагомих досліджень, авторської динаміки, тематичних кластерів та міжнародної співпраці щодо аналізу кінетики та кінематики виконання плоскої та топ-спін подач у тенісі.

Висновки. Отже, дослідження консолідувало наявну інформацію та визначило потенційні шляхи подальшого розширення спектра міждисциплінарних досліджень у галузі техніки виконання подач у тенісі.

Ключові слова: біомеханіка, теніс, аналіз кінетики та кінематики, плоска подача, подача із сильним верхнім обертанням, динаміка подачі, бібліометричний аналіз, програмне забезпечення VOSviewer.

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Cite this article as: Kumar, S., Das, R., Bairagi, K. & Singh, M. (2024). Serve Dynamics: Applying a Bibliometric Approach in the Kinetics and Kinematics Analysis for Flat and Topspin Serves in Tennis. *Physical Education Theory and Methodology, 24*(5), 819-828. https://doi.org/10.17309/tmfv.2024.5.18

Received: 18.06.2024. Accepted: 09.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fizičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Review article

Physical Training Methods to Improve the Physical Condition Components of Elite Taekwondo Athletes in The Kyorugi Category: A Systematic Review

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Accepted for Publication: September 9, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.19

Abstract

Objectives. The study aimed to provide a systematic review of physical training methods to improve the physical condition components of elite taekwondo athletes in the kyorugi category.

Materials and methods. An extensive literature assessment of earlier research was carried out. The objective was to examine articles published between 2020 and 2024 that describe strategies for improving the physical condition component of taekwondo athletes. The electronic search was conducted using Google Scholar, PubMed, Web of Science, and Scopus. The articles that addressed methods for enhancing physical condition through exercise were compiled.

Results. Sixty publications used training approaches to enhance the physical condition component of elite taekwondo athletes in the kyorugi category. Based on the physical state that is assessed and improved, items are categorized. Among the physical training methods that can be applied in the Taekwondo category of kyorugi are plyometric training, circuit training methods, speed, agility, and quickness (SAQ) training; strength training, endurance training, flexibility training, reaction training, power training, coordination training, balance training, resistance training, and functional training.

Conclusions. After thorough analysis, several training techniques have been shown to be effective in enhancing the physical attributes of elite taekwondo athletes in the kyorugi category. These attributes include flexibility, response, strength, power, coordination, agility, speed, balance, and VO_2max.

Keywords: systematic review, taekwondo, kyorugi, physical condition components.

Introduction

The physical challenge of taekwondo is shown in the level of activity and physiological reactions that take place throughout a tournament. Corresponding physiological responses are associated with an individual's psychological condition. This is consistent with Nugroho's assertion that people may effectively and appropriately handle the stress they encounter and overcome obstacles in their lives, which is defined by control, commitment, and difficulties (A. R. Nugroho, 2023). In-depth individual counselling is required in order to offer substitute answers (Firmawati, 2023). The goal of counselling is to help people understand who they are, get past obstacles in their personal, social, emotional, or academic lives, and reach their full potential in a variety of spheres of life (Rababa et al., 2022). Similar to this, practicing taekwondo-in calls for excellent physical and psychological health (Ouergui et al., 2022). The degree to which a person's body is in good shape or not is determined by their physical state (Gallardo & Garcia-unanue, 2023). In order to withstand the physical demands of competing at a high level of competition, taekwondo-in must be in optimal physical condition (Ms & Jun, 2022). In addition to providing a structured strategy for reaching long-term professional objectives or official competition preparation, training sessions are an element of attempts to satisfy physical needs (Pryimakov et al., 2023).

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Physical conditioning, which tries to enhance biomotor skills and optimize physiological capacity, is the most crucial aspect of taekwondo training (Sim et al., 2022). In line with the training objectives, physical training can also be accomplished in a manner that is focused on growth and structure (Hermawan et al., 2021; Jariono, Nugroho, et al., 2021; Jariono, Nurhidayat, Sudarmanto, et al., 2021; Jariono & Subekti, 2020; H. Nugroho et al., 2021). Due of the intricate technical and tactical content of taekwondo. The only methods utilized to determine the elements of physical condition are the tournaments and training of Indonesia's top taekwondo competitors. Since Taekwondo-in is a cohesive unit, it is impossible to dissect their performance into its component elements. As a result, training plans that are tailored to the needs of the sport are created. Because of this, the goal of this study was to evaluate the training methods employed to enhance the taekwondo-in physical condition component and to compile the results of all the studies. in order to observe the taekwondo athletes' physical conditioning training procedure.

Taekwondo has extensive technical and tactical content; thus, physical training can also be done in its own style that is aimed towards the training goal from a structural and developmental point of view. The components of physical fitness are determined by the championship activity itself. The physical state of elite taekwondo athletes is a functional unit that works as a whole; hence, it is impossible to dissect their performance into its component elements. This results in the creation of a training regimen tailored to the specific requirements of the sport. Therefore, in order to monitor the process of physical conditioning exercises that are in line with taekwondo athletes, this study attempts to investigate the training strategies used to enhance the physical condition of taekwondo-in and explain the findings of each study.

Materials and Methods

Database and Search Profile

This systematic review is carried out using electronic searches on Google Scholar, Web of Science, Scopus, and PubMed. The terms "training" and "Taekwondo" are combined while conducting electronic searches. The search strategy is divided into four parts. Initially, 800 papers were located by electronic searches of the PubMed, Web of Science, Google Scholar, and Scopus databases. The second round of screening involved 200 article titles and abstracts and 500 items were eliminated. There were now 100 articles after 100 things were removed for various reasons. The third step involves a comprehensive evaluation and analysis of the entire work, covering the title, abstract, methodology, results, discussion, and conclusion. Following a thorough review of the articles, forty were disqualified for not fulfilling the prerequisites for membership. Reading the relevant document is the fourth step. As of right now, fresh studies have yet to be included. Thus, a total of sixty publications exists. The systematic review started in January 2020 and will be updated every three months until March 2024. Table 1 outlines the search tactics for the databases Google Scholar, Web of Science, PubMed, and Scopus, as well as the historical context of the searches. Table 2 then explains the inclusion and exclusion criteria. Papers for meta-analysis were chosen using the PRISMA Statement for Meta-analysis, which covers Identification, Eligibility Screening, and Inclusion, after the literature was reviewed (Page et al., 2021) (Figure 1).

Methodological Quality Assessment

Eleven PEDros (Physiotherapy Evidence Database) criteria were used to evaluate the quality of the examined publications, and their methodological quality was also evaluated. Good articles help users overcome obstacles like time constraints and poor critical thinking abilities, and they also make it simpler to incorporate high-quality clinical research into clinical practice. According to Moseley et al. (2020), articles with a score of eight to eleven are regarded as having high methodological quality, articles with a score of four to seven are regarded as moderate, and articles with a score of four or less are not evaluated. Clinical practice guidelines and systematic reviews are not evaluated (Moseley et al., 2020).

Moderator Evaluation

Aiming to provide data with six or more subgroups for comparison (e.g., female versus male; Pencak Silat versus

Table 1. Shows the search technique (code line) and search history background for each database

The search's date	Databases	Keywords
January 2020	Google Scholar, PubMed	"Plyometric training", "Circuit Training",
March 2021	Google Scholar, Web of Science (Core Collection), Scopus, and PubMed	"Plyometric training", "Circuit Training", "Speed, Agility, and Quickness (SAQ)", "Strength", "Endurance", "Flexibility", "Reaction", "Power", "Coordination", "Balance", "Resistance", "training"
May 2022	Google Scholar, Web of Science (Core Collection), Scopus, and PubMed	"Plyometric training", "Circuit Training", "Speed, Agility, and Quickness (SAQ)", "Strength", "Endurance", "Flexibility", "Reaction", "Power", "Coordination", "Balance", "Resistance", "training"
June 2023	Google Scholar, Web of Science, Scopus (Core Collection), and PubMed	"Plyometric training", "Circuit Training", "Speed, Agility, and Quickness (SAQ)", "Strength", "Endurance", "Flexibility", "Reaction", "Power", "Coordination", "Balance", "Resistance", "training", and "Functional training"
March 2024	Google Scholar, Web of Science, Scopus, and PubMed (Core Collection)	"Plyometric training", "Circuit Training", "Speed, Agility, and Quickness (SAQ)", "Strength", "Endurance", "Flexibility", "Reaction", "Power", "Coordination", "Balance", "Resistance", "training", and "Functional training"

Table 2. Inclusion and exclusion criteria of a systematic review of physical activity

Classification	Criteria	
	Inclusion	Exclusive
Population	Athletes practicing taekwondo are in good health and have no limitations on their level of competition, gender, or age	Individuals with health issues (such as recent surgery or injury) are prohibited from participating in scheduled circuit training and plyometric exercise
Intervention	Programs that involve unilateral and bilateral leaps and last at least three weeks, such as plyometric training and circuit training, typically employ pre-stretching or Countermovement, which emphasizes cycles of stretch-shortening	The exercise intervention was devoid of any Plyometric workouts, circuit training (such as training treatments that focus solely on upper body plyometrics), or plyometric exercise interventions when combined with other training interventions, jump training programmes make up less than 50% of the whole training load (volume, e.g., number of exercises) (e.g., high-load resistance training)
Comparator	The group under control is traditional sports training, alternative training methods, physical activity, and sedentary	I do not have a control group
Result	At least one measurement was taken both before and after the intervention exercise that is related to aspects of physical condition (e.g., body fat; countermovement jump height) and sport-specific performance (e.g., kicking speed)	Primary data and follow-up need to be included

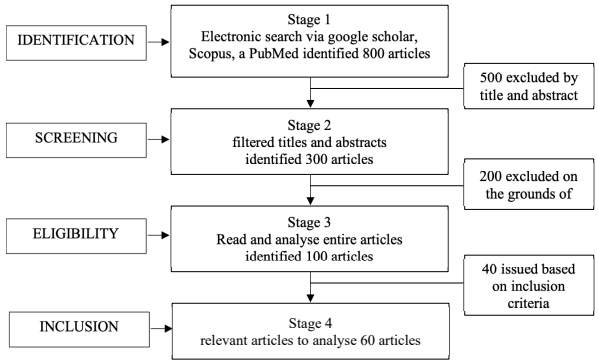

Fig. 1. Diagram of the search process flow

taekwondo; Physical Training Methods (PTM) and Physical Condition Components (PCC) less than eight weeks compared with PTM and PCC more than eight weeks), moderator analyzes were planned. For subgroup allocation, the median split technique (Moran et al., 2017, 2018) was applied as appropriate.

Results

Number of Results Reviewed

800 papers were located in the first round of computerized searches using Google Scholar, Web of Science, Scopus, and PubMed; no duplicate articles were discovered. The next step involved filtering 500 articles using the title and abstract; the second stage involved filtering again using the title and abstract; 200 articles were removed along with a justification; the third stage involved reading and analysing every article by determining the outcomes, leaving 100 articles to be reviewed overall. Out of the 100 articles, 40 were discarded, leaving 60 articles that satisfied the notability standards according to the PEDro scale. The physical condition component is used to group this item (table 3).

Exercise Significance Results

Regardless of gender, age, professional level, novice or expert athletes, or the kind of training done, of the 60 studies that were chosen and examined, an overall analysis of the 60 publications produced noteworthy findings regarding the physical state of taekwondo athletes.

Discussion

Plyometric Training

A workout regimen that improves both strength and speed is called plyometric training (Subathra et al., 2023). This exercise is necessary for taekwondo athletes because it tests their ability to respond forcefully and swiftly in both attacking and defending situations (Kim & Lee, 2023). Accordingly, it has been demonstrated that plyometric exercise increases explosive action (Thapa & Ramirez-campillo, 2023). This can be explained by the fact that several exercise kinds are done, which could affect the exercise's outcomes (Moran et al., 2023). As noted by Fischetti et al. When coupled with other activities, Fischetti, et.al. (Fischetti et al., 2018), which mixed weight training and plyometric training in a three-group experiment, produced varying results (Deng et al., 2023). Three groups were assigned: one for weight training exclusively, another for weight training combined with plyometric exercises, and a control group (Huang & Huang, 2023). After six weeks of training, the results demonstrated that plyometric training more successfully enhanced sprinting, acceleration, deceleration, and jumping than did weight training alone (Campillo et al., 2023). Better outcomes for enhanced muscle performance are obtained

Table 3. Features and outcomes of taekwondo athletes' physical condition component training programs

N.	Author, Year	Physical Condition Variable	Training Type	Sig.(p)
1	Bujak & Gierczuk, 2024	Power, physical performance	Anaerobic Performance and Competitive Experience	Sig.
2	Taha, 2024	physiological capacity and technical performance	Training Program Using High-Intensity Interval Training	Sig.
3	Vincent, 2024	Balance and Single-Leg	Functional performance	Sig.
4	Messaoudi et al., 2024	Plyometric – based conditioning activity (CA)	Combination with a plyometric-based CA during warm-up setups an individualized warm-up strategy and serves to improve the subsequent specific performances	Sig.
5	Boyanmis, 2024	Strength Measurement	Herman Tainer, Manual Tester, and Standing Long Jump	Sig.
6	Fadhila et al., 2024	Weight Loss	Circuit Body Weight Training	Sig.
7	Niewczas et al., 2024	Psychomotor skills	With training experience, body mass, and technical-tactical skill levels	Sig.
8	Thurlow et al., 2024	Physical Fitness and Physiological Adaptation	Repeated-Sprint Training	Sig.
9	Tropin et al., 2024	Strength performance	Static-dynamic exercises	Sig.
10	Lubis et al., 2024	Body composition, power, and kicking speed	Six-week plyometric, functional, and interval trainings	Sig.
11	Tomasz et al., 2024	Strength	Effective Mass on the Strength of Side and Turning Kick	Sig.
12	Kim & Lee, 2023	Physical Fitness and Electronic Hogu Hitting Ability	Basic physical fitness (muscle endurance, flexibility), isokinetic muscle function (knee endurance, low back strength),	Sig.
13	Arnando et al., 2024	Ability	Agility Training	
14	Li et al., 2023	lower limb explosive strength	Circuit strength combined with blood flow restriction training	Sig.
15	Khazaei et al., 2023	Bio motor capacities	Traditional resistance training and functional training	Sig.
16	Kim & Lee, 2023	Body Composition, Physical Fitness and Electronic Hogu Hitting Ability	12 Weeks Weight Training and Plyometric Training	Sig.
17	Kudryavtsev et al., 2023	Physical fitness and sport performance	Short-term functional training intervention	Sig.
18	Jeong et al., 2023	Effects of Taekwondo Training on Growth Factors in	A Systematic Review and Meta-Analysis of Randomized Controlled Trials	Sig.
19	Ouergui et al., 2023	Plyometrics, repeated techniques	Effects of conditioning activity mode, rest interval and effort to pause ratio on post-activation performance enhancement	Sig.
20	Nabilpour et al., 2023	Psychological skills, anaerobic fitness, and aerobic fitness	An investigation into the associations between	Sig.
21	Thapa & Ramirez-campillo, 2023	Physical Fitness	A Systematic Review with Meta-Analysis, Plyometric-Jump Training	Sig.
22	Nia et al., 2023	Limb Muscle Power Components, Leg Length, and Pelvic Flex	Contribution of Dollyo Chagi's Kick	Sig.
23	Abadi, 2023	Metacognitive Beliefs and Sports Performance	The Effect of Mental and Physical Training	Sig.
24	Hikmah et al., 2023	Increasing agility	ladder drill training effective	Sig.
25	Fajar et al., 2023SAQ, and Traning Circuit	Improving leg power and Dolyo Chagi kick speed	plyometric, SAQ, and circuit training methods	Sig.
26	Fajar, 2022	Power, Agility, and Resting Pulse	Plyometric Exercise and Ladder Drill	Sig.
27	Iwan Hermawan et al., 2022	Physical condition	Descriptive study	Sig.
28	Noor et al., 2022	Psychological and Physical Factors	Systematic Review	Sig.
29	Pryimakov et al., 2022	Physical development, speed and strength fitness	Relationships between the parameters	Sig.
30	Ambro, 2022	Physical Fitness	CrossFit Training	Sig.
31	Rydzik et al., 2022	Physical Fitness	Training Experience	Sig.

Table 3 (continued)

N.	Author, Year	Physical Condition Variable	Training Type	Sig.(p)
32	Harbili et al., 2022	Strength	bilateral isokinetic and isometric strength differences	Sig.
33	Taati et al., 2022	Aerobic power, anaerobic fitness, and agility performance	Specific field test for estimating aerobic power, anaerobic fitness, and agility performance	Sig.
34	Ouergui et al., 2022	Psychological and Physical Performances	Low Dose of Caffeine Ingestion Combined with Conditioning Activity	Sig.
35	Rocchi et al., 2022	Endurance and power	High intensity functional training	Sig.
36	Srianto & Siswantoyo, 2022	Speed and Flexibility	Biomotor Analysis	Sig.
37	Ansharudin et al., 2022	Agility and Speed	Traditional Sports Practice	Sig.
38	Rocchi et al., 2022	Endurance and power	High intensity functional training	Sig.
39	Jariono, Nurhidayat, Nugroho, et al., 2021	Special preparatory physical condition training program, pre-competition physical condition training program, main competition physical condition training program, transition physical condition training program, and compiling an exercise program	Strategies to improve jump service skills	Sig.
40	Waffak et al., 2022	Agility	Water exercise and sand exercise training methods	Sig.
41	Gen, 2021	Athletic Performance	Plyometric Training Program	Sig.
42	Alfian Noha Zulkarnain, Agus Kristiyanto, 2021	Speed and agility	Body weight strength training and plyometric	Sig.
43	Ruddock et al., 2021	High-Intensity Conditioning	Practical Recommendations	Sig.
44	Baek et al., 2021	Training on Body Composition	Training on Body Composition: A Systematic Review and Meta-Analysis	Sig.
45	Fachrezzy et al., 2021	Physical condition, self-confidence, and comparison of leg muscle explosive power and core stability	Kicking ability	Sig.
46	Junior, 2021	Strength-endurance	Developing	Sig.
47	Chun et al., 2021	Anaerobic Power and Dynamic Postural Stability	Core Balance and Plyometric Training	Sig.
48	Ojeda-aravena et al., 2021	General and Specific Physical Fitness	Technique-Specific Protocol with High-Intensity Intervals	Sig.
49	Sung et al., 2021	Preliminary Study of Pre-Season Taekwondo Preparation Strategy	Personal Isolation Training	Sig.
50	Yilmaz, 2021	Performance	Different Flexibility Studies	Sig.
51	Enrique et al., 2020	Improves specific performance	High-intensity interval training	Sig.
52	Zadoroznha, 2020	Tactical training of elite athletes in Olympic combat sports	Practice and experience	Sig.
53	Khayyat et al., 2020	Physical, physiological and psychological	Descriptive	Sig.
54	Silva et al., 2020	Acute weight loss and physical performance	12 hour-fasting promoted by breakfast omission	Sig.
55	Alp & Gorur, 2020	Explosive Strength and Anaerobic Power Performance	Comparison of Taekwondo and Karate Athletes	Sig.
56	Lee et al., 2020	Functional ankle instability	Plyometric versus ankle stability exercises on lower limb biomechanics	Sig.
57	Prieske et al., 2020	Anthropometry, Body Composition, and Physical Fitness	An Exploratory Study	Sig.
58	Vasconcelos et al., 2020	High-Intensity Interval Training in Combat Sports	A Systematic Review with Meta-Analysis	Sig.
59	Orkun AKCAN et al., 2020	Body Composition and Muscular Strength	High Intensity Interval Training in Different Forms Applied to Combat Athletes	Sig.
60	Torrealba et al., 2020	Performance	high-intensity interval training in hypoxia	Sig.

by gradually increasing the number of plyometric activities (Henrique et al., 2023).

Circuit Training Methods

According to Stojanović et al (Stojanović et al., 2023) the circuit training approach consists of a sequence of exercises where each post has a single type of action. The number of posts can range from 4 to 12. One of the more sophisticated training techniques for enhancing general physical health, including the fundamental biomotor components, is circuit training (Ziyaiyan et al., 2023). Circuit training is defined as training that consists of a set of distinct exercises performed consecutively and continuously at each post during a single lap (Sunarto et al., 2023). Leg muscle explosiveness can be greatly increased by circuit training, especially circuit training that incorporates strength and speed training movements (Subathra et al., 2023).

Speed, Agility, and Quickness (SAQ) Training

One of the training techniques that has gained popularity is speed, agility, and quickness (SAQ), which affects the development of fundamental skills to help athletes become more proficient with greater speed and accuracy (Sharma, 2023). One of the most effective contemporary sports training techniques is SAQ exercise, which promotes quick movements and enhances agility, response speed, fitness, explosiveness, and non-aerobic capacity (Ateef Abdul-Khaleq Ahmed, 2023). The activities in the training program are suitable for enhancing speed and agility, and they also lead to the creation of a more relevant and functional motor program that regulates intricate intramuscular coordination (Singh, 2023). Via neuromuscular growth, SAQ can also acquire the ability to govern gestures. Reprogramming the neuromuscular system to increase mobility efficiency is intended to enhance multidirectional mobility and explosiveness.

Strength Training

According to (Gäbler et al., 2018) strength is the most crucial element that forms the basis for other physical condition elements and is a prerequisite for nearly all sports. To grab the coach's attention, you must therefore increase the strength component's capacity. Strength is a physical attribute that can be enhanced to the fullest extent possible based on the demands of each sport (Jamka et al., 2022). Sports games will not require the same level of strength needed for weightlifting (Murlasits et al., 2017). The ability of a muscle to execute continuous or repetitive work against resistance with maximum effort is another definition of muscle strength (Jamka et al., 2021).

Endurance Training

Anaerobic endurance is required in taekwondo sports for competitive levels of play. Taekwondo competitors must use all of their physical prowess to execute attacks in the fast-paced, high-tempo championship (Demir, 2023). One of the most important components of motor skills is endurance, which comes from a student's psychological ability to support movement at any given time (Bahtra et al., 2023). The capacity of muscles to sustain high-intensity activities or static positions is known as muscle endurance (Markov et al., 2023). A condition that emphasizes the ability to work continuously in an aerobic environment is called endurance. The ability to perform a task for a long period of time without experiencing excessive fatigue is called endurance (Matomäki et al., 2023). When it comes to muscle training, endurance is the capacity to train a muscle or set of muscles in a specific amount of time, whereas the body's organs' capacity to function within a specific time frame is measured by the energy system (Bruggisser et al., 2023).

Flexibility Training

The development of athletic accomplishments depends heavily on the flexibility component. Because other aspects of physical conditions are significantly impacted by flexibility. One of the things that leads to subpar performance and ineffective technique is a lack of flexibility, which can also result in excessive stress and tears in the muscles during exercise (Vetter et al., 2023). According (Bouguezzi et al., 2023) state that insufficient flexibility is the reason for both inadequate endurance and a lack of speed. The muscles will have to work harder to overcome the resistance of dynamic and prolonged exercises if there is insufficient flexibility (Warneke, Wohlann, et al., 2023). One may become faster and more agile, and their energy consumption may even decrease, by expanding their range of motion in their ankles, pelvic, buttocks, and shoulder joints. to enable sportsmen to exert more energy and work for longer (Warneke, Wirth, et al., 2023). Elevated testing of flexibility could be linked to strain-induced modifications in the muscle-tendon complex (Wohlann et al., 2023). According to (Sobrinho et al., 2023), multicomponent training in conjunction with flexibility training improves joint angles and body alignment while also lowering blood pressure.

Reaction Training

The ability to initiate a kinetic response as fast as possible in response to a stimulus is known as reaction speed (Rozi et al., 2023). The degree to which the perception situation, the kinetic response to be executed, and the state of the physical environment are recognized all influence how quickly an individual reacts (Sullivan & Jeong, 2022). Having quick reactions is crucial for enhancing athletic performance. Reaction speed is immediately used to generate effective, efficient, and economical motions, facilitate the mastery of advanced methods, coordinate multiple movements, and aid in self-adjustment to the opponent and his surroundings (Romanenko et al., 2022).The sports involved will be impacted by speed. in connection with power. This is due to the fact that power output increases with speed. This is so because power is built through speed.

Power Training

The attack or defence's computed value is determined by how accurately, rapidly, steadily, and strongly it strikes the target field; this power is essential to any strategy that is used (Taati et al., 2022). The power in question is the strength associated with the arms and legs, which are the

fighting equipment used in taekwondo (Rocchi et al., 2022). A taekwondo practitioner with strong arm muscles can execute punches and other arm-powered attacks with ease. This along with their excellent coordination will allow them to score the desired number of points.

Coordination Training

Technical proficiency and physical prowess have a major role in taekwondo skills (Brach et al., 2022). Coordination is one of the physical qualities a taekwondo athlete needs to have in order to execute offensive moves (Lyuchkova et al., 2022). The capacity to combine a wide range of movements into one or more targeted motion patterns is known as coordination (Miftachurochmah & Sukamti, 2022). Exercises that include flexing the body are designed to strengthen the muscles, respiratory system, and central nervous system. Regular exercise routines that incorporate balance and agility exercises will improve motor coordination.

Balance Training

Exercises for improving balance can also assist prevent injuries to the body and increase strength, flexibility, and ability (Mccrum et al., 2022; Sarasso et al., 2022). The capacity to keep the neuromuscular system in an efficient position or attitude to move, whether attacking or defending, is known as balance.

Resistance Training

For optimal results, resistance training (RT) combined with aerobic training is recommended (Serafim et al., 2023). As a result of this knowledge growing and the desire to increase physical activity, various RT techniques have been developed (Way et al., 2023). This approach gives little weight to aesthetics or sports performance enhancement when evaluating health, well-being, and quality of life (Burgos-jara et al., 2023). Resistance training is a type of physical activity that uses specialized equipment to enhance muscular function and shape (Weakley et al., 2023). In order to increase muscle strength, endurance, mass, growth, and hypertrophy, this exercise will teach muscles to contract against the instruments utilized (Jukic et al., 2023).

Functional Training

Specialized physical exercises that develop strength throughout the body are part of functional training (Raphael et al., 2023). The athlete's mobility and stability will improve when they execute the exercises during functional training appropriately (Wang et al., 2023). Exercises known as "functional training" involve the use of basic instruments or no tools at all, such as one's own body weight (Oliveira et al., 2023). Sports motions that are modified to the body's movements during everyday activities are generally referred to as functional training (Pantoja-cardoso et al., 2023).

Conclusions

Following a detailed examination, it was discovered that a large number of training regimens were created with the goal of enhancing the taekwondo competitors' physical attributes, such as strength, muscular strength, speed and acceleration, flexibility, agility, explosiveness, and balance.

Acknowledgment

This research project is an autonomous study. The State University of Jakarta, all parties participating in this research, and the full team are appreciated by the author for their help with the reference search.

Conflict of interest

All authors declare no conflict of interest.

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Методи фізичної підготовки щодо покращення складових фізичного стану елітних спортсменів з тхеквондо у категорії «кьоругі»: Систематичний огляд

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 13 с., 3 табл., 1 рис., 120 джерел.

Мета дослідження. Метою дослідження було проведення систематичного огляду методів фізичної підготовки щодо покращення складових фізичного стану елітних спортсменів з тхеквондо у категорії «кьоругі».

Матеріали та методи. Здійснено комплексний літературний аналіз попередніх досліджень. Завдання полягало у дослідженні статей, опублікованих між 2020 та 2024 роками, які описують стратегії поліпшення показників складової фізичного стану спортсменів з тхеквондо. Електронний пошук здійснювався за допомогою наукометричних баз даних Google Scholar, PubMed, Web of Science та Scopus. Було відібрано статті, в яких розглядалися методи покращення показників фізичного стану шляхом виконання фізичних вправ.

Результати. Шістдесят публікацій містили інформацію щодо застосування тренувальних підходів для покращення складової фізичного стану елітних спортсменів з тхеквондо у категорії «кьоругі». Залежно від фізичного стану, показники якого оцінюються та покращуються, статті класифіковано за категоріями. Серед методів фізичної підготовки, які можуть застосовуватися в тхеквондо категорії «кьоругі», варто зазначити пліометричні тренування, методи кругового тренування, тренування на швидкість, спритність і моторність (SAQ); силові тренування, тренування на витривалість, тренування на гнучкість, тренування на розвиток реакції, силові тренування на здатність долати опір за найкоротший проміжок часу, тренування на координацію, тренування на рівновагу, тренування з опором і функціональні тренування.

Висновки. Після проведення ретельного аналізу було встановлено ефективність кількох тренувальних методик щодо покращення фізичних якостей елітних спортсменів з тхеквондо у категорії «кьоругі». До таких якостей належать гнучкість, швидкість реакції, сила, потужність, координація, спритність, швидкість, рівновага та показник максимального споживання кисню (VO_2max).

Ключові слова: систематичний огляд, тхеквондо, кьоругі, складові фізичного стану.

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Cite this article as: Fachrezzy, F., Maslikah, U., Hermawan, I., Jariono, G., Nugroho, H., & Syahruddin (2024). Physical Training Methods to Improve the Physical Condition Components of Elite Taekwondo Athletes in The Kyorugi Category: A Systematic Review. *Physical Education Theory and Methodology, 24*(5), 829-841. https://doi.org/10.17309/tmfv.2024.5.19

Received: 11.07.2024. Accepted: 09.09.2024. Published: 30.10.2024

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Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ

ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Review article

Analyzing Sports Biomechanics of Hurdling Training: A Systematic Review

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Accepted for Publication: September 19, 2024
Published: October 30, 2024

DOI: 10.17309/tmfv.2024.5.20

Abstract

Background. Hurdling is a dynamic and technically demanding sport within athletics. It requires a unique combination of speed, agility, coordination, and strength to support good technique and achievement. The ability to excel in this sport depends on the athlete's mastery of these components, making it an interesting subject for sports science research.

Objectives. This study aimed to evaluate existing research on sports biomechanics as it relates to improving hurdling performance.

Materials and methods. The study was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology of the relevant literature. A total of 15 articles published between 1990 and 2023 were identified as relevant to the focus of the study and selected for in-depth analysis.

Results. The findings showed that sports biomechanics research in hurdling training has mainly concentrated on the following key areas: kinematics analysis, the application of technology, and the potential injury studies. Although significant progress has been made in understanding the biomechanics of hurdling training, this study suggests the need for further and more comprehensive research. The research mentioned should delve deeper into the biomechanical factors influencing performance in order to develop optimal training methods and injury prevention strategies.

Conclusions. This review underscores the importance of continued research in this area, as it has the potential to enhance training approaches and improve athletic performance in hurdling.

Keywords: hurdling training, kinematic analysis, technology applications, sports injuries, kinetic analysis.

Introduction

Sports science has undergone a significant development from mere physical activity to a more structured physical activity (Shestakov & Fomichenko, 2021). Sports science began to become part of a legitimate academic field with numerous scientific studies in sport and physical training (Yan & Girard, 2023). Advances in technology and research methodologies resulted in the expansion of the scope of sports science (Schweinbenz, 2016). Sports science is a scientific field that includes aspects such as sports physiology (Lundgren et al., 2015), sports biomechanics (Forte et al., 2021), sports psychology (Zhang et al., 2021), sports nutrition (Amawi et al., 2022), sports rehabilitation (Moylan & Horne, 2013), and sports technology and analysis (Godfrey et al., 2023). The use of wearables, GPS and other software, is aimed at monitoring and improving the performance of athletes (Yu et al., 2022). In addition, sports science also includes the study of the social and cultural aspects of sport, as well as issues such as inclusion, gender and ethics, indicating an increasingly holistic approach to understanding and optimizing athletic performance (Strudwick, 2023).

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The advancement of sports science has significantly contributed to understanding the complexities of athletic performance across various disciplines (Edouard et al., 2021). One example that can be observed is in the hurdle race number. Hurdles requires high coordination, balance, and timing to integrate sprinting with the technical demands of passing obstacles (Yendrizal et al., 2023). Hurdles represent a unique blend of techniques requiring athletes to master those combinations and achieve optimal performance (López Del Amo et al., 2018). Optimizing this performance is done through structured and organized training (Terrell & Ficquette, 2023). Evaluation and conditioning of athletes must be carried out, therefore the athlete performance can be monitored regularly (Nie, 2022).

The implementation of sports science, one of which is in sports biomechanics, becomes a means or media for evaluation and training conditioning for coaches and athletes (Navarro et al., 2021). The integration of biomechanical analysis into hurdling is pivotal for dissecting the multifaceted elements that contribute to an athlete's success (Adashevskiy et al., 2014). It also provides insight into technique optimisation, injury prevention and performance enhancement (Gaudino et al., 2021).

Biomechanics as a sub-discipline of sports science, plays a crucial role in elevating the understanding and execution of hurdling (Gong et al., 2023). Through the detailed examination of kinetic and kinematic analysis, biomechanics aids in identifying critical factors influencing hurdling efficiency and effectiveness (Hanley et al., 2021; Nagahara et al., 2021). This allows for the precise tweaking of technique, informed by evidence-based practices that can lead to significant improvements in speed, height, nor overall performance (Iskra & Coh, 2011). Biomechanical analysis should consider on aspects such as obstacle clearance technique, step pattern optimisation, and the body angle formed from the jump (Čoh et al., 2020).

This systematic review study aims to evaluate and analyze the development of sports biomechanics research in hurdling training. The competitive nature of hurdling and its technical complexity require innovative methods to enhance athlete performance. This systematic review also aims to explore the current landscape of biomechanics research in hurdling, identifying key findings, gaps in the literature, and potential areas for future investigation. By synthesizing the existing body of knowledge, this review seeks to provide athletes, coaches, and sports scientists with actionable insights that can be applied to training and competition, ultimately pushing the boundaries of what is achievable in the discipline of hurdling.

Materials and Methods

Materials for Analysis

Data collection was conducted on 22nd July 2024, through the SCOPUS website using the keywords "sports" AND "biomechanics" AND "hurdles". Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was applied in this study (Figure 1). During the identification process, there were 43 articles in the period 1990-2023, but not every year of publication related to the keywords used.

Organization of the Study

This was followed by a screening process and found 8 articles that were not related to sports and 20 articles that were not related to sports biomechanics. Based on the screening process, 15 eligible articles were obtained, but the researcher only selected 10 articles. The selection was based on the most citations and the most relevant articles according to the keywords and objectives of this study.

Methods of Analysis

This research is a qualitative method with a systematic review design. The database in this study comes from the SCOPUS database. The selection of the SCOPUS database as a systematic review study material is because SCOPUS is an internationally accredited and credible platform. referred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was applied in this study (Figure 1).

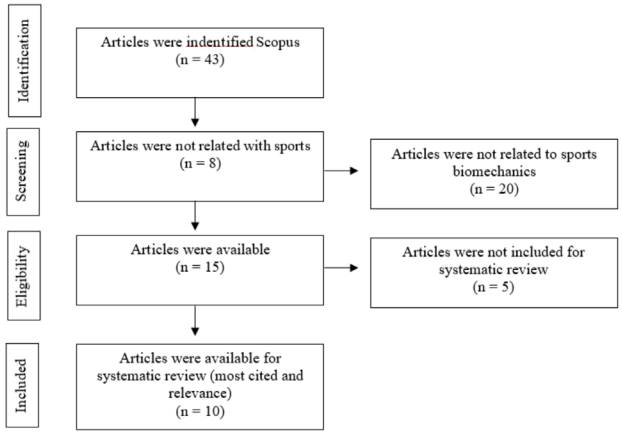

Fig. 1. PRISMA flowchart of the article selection process

Results

Publications of Sports Biomechanics in Hurdles

Research conducted in the field of sports biomechanics, especially in hurdling, has not experienced significant development. This is shown through the presentation of graphs or data based on the analysis of search results according to the keywords used through the SCOPUS database (Figure 2). Based on the results of data collection, research from 1990-2011 was stagnant, there was no significant increase in those

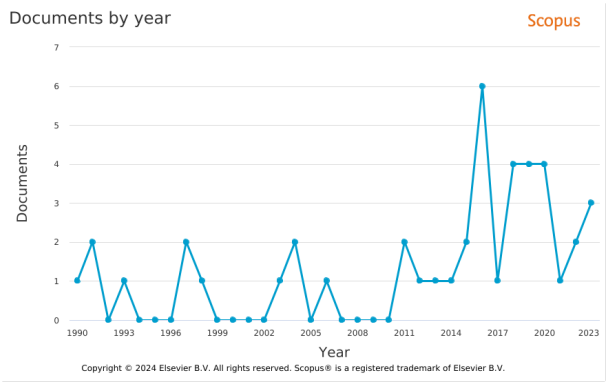

Fig. 2. Publications of sports biomechanics in hurdles

years. The increase began to occur in 2012-2023, with the peak of publication results in 2016 totalling 6 publications. However, the following year experienced a decline, and began to show a stagnant graph.

There is a disclaimer in the research results presented in this graph. The results presented are not all publications that are relevant to the keywords used. The results presented are divided into several fields that are not relevant to the keywords, such as 'gymnastic', 'animals OR dogs', 'economy', and others. Adjustments were not made by the researcher due to the lack of research conducted in the field of sports biomechanics in hurdling. If adjustments are made, the graph will not be formed effectively due to the small number of publications.

Countries Contributed on the Sports Biomechanics in Hurdles

The results in this study are similar to those presented in Figure 2. These results were not adjusted to capture the trend of research development across countries. Although the results are complex, they can be used as a visualisation in observing the developments that occur. So that it can be an evaluation in further research.

Based on the results presented (Figure 3), the United Kingdom (UK) is the country with the most contributions in sports biomechanics in hurdling. This is evidenced by the number of publications as many as 18 articles, more than 2 times that of the United States (US). The US ranked second with the number of publications is 8 articles. European countries occupy the top position and are followed by Australia at number 3. Asian countries are no less existent by ranking 4th and 6th, namely China and Japan. The results presented show that publications in sports biomechanics in hurdling are dominated by countries in Europe.

Systematic Review on the Sporst Biomechanics in Hurdles Training

The articles selected for review were the result of a screening process using the PRISMA method. The selection of articles with the most citations and the most relevant was carried out by the researcher by giving special notations to the articles that had been reviewed. The results of the review obtained 10 best articles that fit the criteria and objectives of this study (Table 1).

Discussion

The application of sports science brings changes and the development in hurdling. Sports science has connections with various fields and results in hurdling training. Especially sports biomechanics which possibly assist the athletes to optimize their performance and minimize the risk of injury (Bartlett & Bussey, 2013). The identification results in the SCOPUS database, presented the research trends about sports biomechanics in hurdles increases dynamically. European countries such as the United Kingdom and the United States are at the top of publications, with 18 and 8 studies respectively. Furthermore, the results of the systematic review are divided into 5 discussion topics. These topics are based on the conclusions of the 10 articles systematically reviewed in this study. The discussion on the systematic review is presented as follows.

Velocity and Angular Momentum as Important Role in Hurdles Training

Velocity and angular momentum are related in the hurdling technique. In Velocity provides momentum to the runner when taking off (Ozaki & Ueda, 2022). Based on

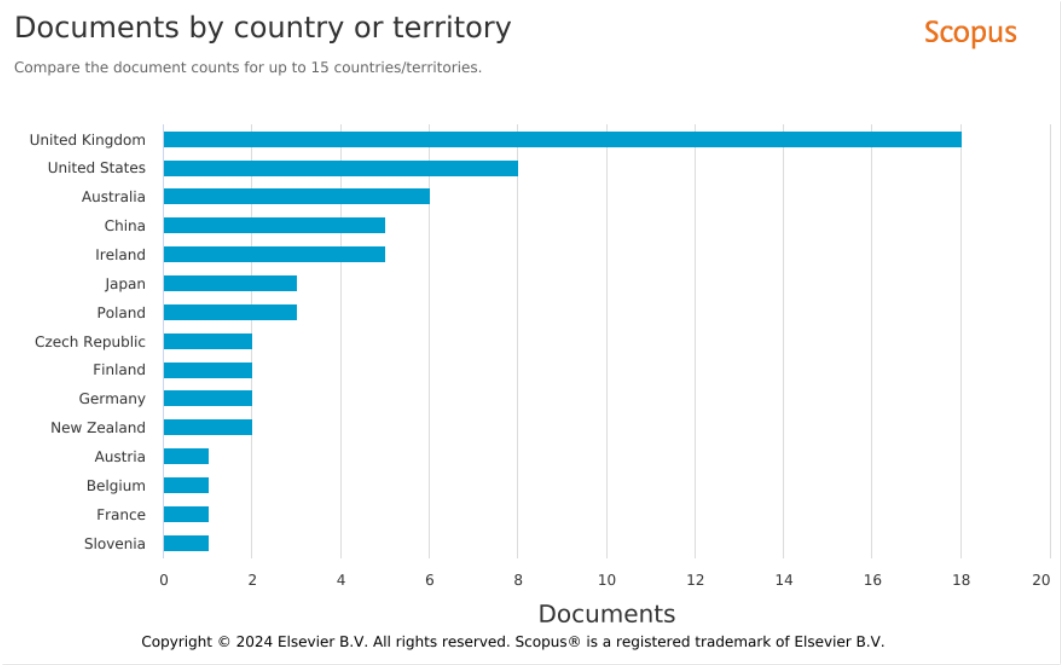

Fig. 3. Countries contributed on the sports biomechanics in hurdles

Table 1. Research results on the sport biomechanics in hurdling training

Author	Research purposes	Sample Characteristics	Study Design	Results
McDonald & Dapena, 1991	To obtain three-dimensional (3D) linear kinematic data on the techniques employed by Olympic-level male and female hurdlers during competition.	Thirty-two hurdlers – 23 men and 9 women – were captured on video using three-dimensional techniques at the 1988 US Olympic Trials.	Cross-Sectional Study	A rise in vertical velocity and a fall in forward horizontal velocity when the hurdle step is being taken off. After the hurdle, the forward velocity was mostly restored during the second support period. The center of mass's (CM) downward descent was not stopped until the second support phase after the hurdle was cleared. For the male participants, the center of mass (c.m.) parabola's peak was situated almost exactly above the hurdle, but for the female participants, it was situated 0.30 m forward of the hurdle. The findings showed that, in comparison to the men, the women used a parabola with a larger margin above the hurdle.
A. Salo & Grimshaw, 1998	To investigate the kinematic variability and sources of variation in sprint hurdle video motion analysis.	Four women and three men competing at the national level in the 100-meter hurdles for Britain offered their time to take part in the research. The women's mass was 62 kg (mean + SD), their height was 1.76 m (mean + SD), and their age was 20.1 years (mean + SD). For the men, the corresponding figures were 1.83 + 0.05 m, 80 + 8 kg, and 26.9 + 1.7 years. The men's and women's personal best times for the sprint hurdles were 14.11–15.38 seconds for the 110-meter hurdles and 13.65–14.15 seconds for the 100-meter hurdles, respectively.	Cross-Sectional Study	When used in conjunction with the analytical system and operated by a single person, the results generated are sufficiently precise and consistent for the majority of variables used in the kinematic analysis of tasks like hurdle clearance. According to the operator and the combination of analytical processes, displacement variables showed the highest degree of repeatability.
Krzeszowski et al., 2016	To create an algorithm for the estimate of parameters for hurdle clearance that are established by analyzing image sequences.	Five hurdlers in various training phases participated in the analysis. Two Polish youth champions and four Polish runners-up were among the candidates whose names were on file.	Cross-Sectional Study	The assessment of tracking quality was conducted using both qualitative visual assessments and ground truth data. By manually matching a 3D model to the hurdlers in the picture, ground truth data were produced.
A. I. T. Salo & Scarborough, 2006	To investigate how an athlete's own performance changes in a sprint hurdles run in terms of technique.	Four athletes—two men and two women—representing national or international standards voluntarily took part in the study and provided their informed consent. The female athletes, identified as Athletes A and B, were 1.68 ± 0.04 m tall, 25.5 ± 2.1 years old (mean ± SD), and weighed 58.5 ± 6.3 kg.	Cross-Sectional Study	On each run, athletes showed a decrease in their running speed over the hurdle at the ninth hurdle compared to the third hurdle. In addition, every participant showed signs of exhaustion during the ninth hurdle clearing. It is noteworthy that the athletes' observed technical modifications were not consistent. Even in situations where weariness may be affecting performance, athletes can learn how to cross the hurdle at a higher horizontal velocity with this method.

Table 1 (continued)

Author	Research purposes	Sample Characteristics	Study Design	Results
Hasenkamp et al., 2017	To analyze the distribution of total body angular momentum between the head, arms, and legs during the women's and men's 110-meter hurdle races. This was carried out in order to evaluate the validity of the theories put out in the literature and, if needed, to provide new explanations.	Thirteen hurdlers—nine female and twenty-three male—were videotaped using three-dimensional techniques during the 1988 US Olympic Trials.	Cross-Sectional Study	The hurdle clearance is contingent upon angular momentum in the negative X direction, which we have designated as "forward rotation." This corroborates the hypotheses previously put forth by other authors. It was found that the majority of the angular momentum is present in the right leg during the initial stages of the airborne phase.
Čoh et al., 2020	To analyze the biomechanical characteristics of the fifth hurdle clearing technique used by two world record holders, Dayron Robles of Cuba (who established a time of 12.87 seconds in 2008) and Colin Jackson of Great Britain (who set a time of 12.91 seconds in 1994), in the 110-meter hurdle event.	Two elite hurdlers from around the world took part in this experiment: Dayron Robles from Cuba (body mass 79 kg, height 191 cm) and Colin Jackson from Great Britain (body mass 75 kg). Both athletes were world record holders in the 110-meter hurdles, their area of expertise.	Comparative Study	The height differential of 10 cm between Dayron Robles and Colin Jackson results in a lower flight parabola for the Cuban athlete during hurdle clearance. In comparison to Jackson's achievement, Robles' technique of hurdle clearance is more effective. It is possible to argue that the strategies each athlete used to clear the hurdle have already reached the peak of their effectiveness.
Otsuka & Isaka, 2019	To compare different competitive-level 400-meter hurdlers within and between groups in order to assess their running pace and step characteristics.	14 male 400-meter hurdlers competing at the national level and 13 male world-class hurdlers (best records: 49.28 ± 0.41 s and 47.71 ± 0.44 s, respectively). Between 2010 and 2014, three of the athletes were ranked in the top 20, with one person accomplishing this accomplishment twice. These two instances—the first in the World rankings and the second in the Japan rankings—occurred in different rankings.	Observational Study	The national-level hurdlers' times were far longer than those of the elite hurdlers, as evidenced by a comparison of their times from the first and second parts of the competition. SL and SF did not significantly differ between national-level hurdlers and world-class hurdlers during the later phase. Comparing competitors in the same group showed that none of them shown a distinct preference for running faster during the beginning part of the race, as indicated by their shorter finishing times.
Falbriard et al., 2020	To determine whether inertial and magnetic sensors put on shoes may be used to identify the leading leg in 400-meter hurdles and detect hurdle clearance. Furthermore, the study sought to offer an examination of the spatiotemporal aspects of the hurdlers inside the intervals delineated by their positions.	Ten male athletes (aged 22 ± 4 years, measuring 183 ± 2 cm, weighing 69 ± 6 kg, and clocking 57 ± 3 seconds) and six female athletes (aged 23 ± 3 years, measuring 165 ± 4 cm, weighing 55 ± 2 kg, and clocking 64 ± 3 seconds) volunteered to compete in a single 400-meter hurdles event, each of which was outfitted with an IMU. Six female participants (165 ± 4 cm in height, 55 ± 2 kg in weight, 64 ± 3 s in time) volunteered to compete in a 400 m hurdles event that was outfitted with IMUs.	Cross-Sectional Study	The leading leg could be identified with 100% accuracy and hurdle clearance could be detected with 100% accuracy using the flight phase length method. Additionally, we achieved 100% accuracy in hurdle clearance detection and 99.7% accuracy in identifying the leading leg in a unipedal setup by merging the swing phase duration with the foot orientation.

Table 1 (continued)

Author	Research purposes	Sample Characteristics	Study Design	Results
Q. Li, 2014	To analyse the hurdle knee joint, ankle joint, and elbow and shoulder injuries from a medical perspective, combining this with an understanding of human structure. It makes suggestions on how to prevent and treat each type of injury, with the aim of standardising technical motions, reducing hurdler injury, and contributing to the development of hurdle techniques in our country.	A questionnaire survey was conducted on 400 hurdlers, with 250 male and 150 female participants.	Survey Study	In the research process, a questionnaire was initially distributed to 400 athletes, with the aim of identifying the most common body parts affected by sports-related injuries. The results indicated that ankle, knee, shoulder and elbow joints were the most frequently injured areas, with respective incidences of 31 %, 17 %, 16 % and 16 %.
Schmidt et al., 2020	The original paper is discussed in this commentary, with an emphasis on the ecological validity and the suitability of MIMU systems in field-based contexts, such elite athlete training or competition.	A recent paper entitled "Hurdle Clearance Detection and Spatiotemporal Analysis in 400 Meters Hurdles Races Using Shoe-Mounted Magnetic and Inertial Sensors" was published.	Review Study	We suggest that both the change of the data processing techniques and the basic assumptions underlying the error estimation are inappropriate for use in such an applied environment. As such, these metrics do not fairly represent the real performance of athletes at a modest skill level.

(McDonald & Dapena, 1991), velocity will increase when the athlete's position passes the hurdle, and will decrease when the athlete passes the hurdle. Optimal velocity will create effective angular momentum. Angular momentum created with width and height, will minimise the risk of athlete failure in jumping over the hurdle (Hasenkamp et al., 2017). In addition, through good angular momentum will have an impact on the smooth landing process as well. Thus, the risk of leg injury from hurdles athletes can be minimised.

Variables for Kinematic Analysis of Hurdling Training

Two-dimensional analysis or kinematics analysis supports the techniques in sport training and competition (Peebles et al., 2021). Kinematics analysis in hurdles reviews several aspects that affect the outcome of hurdle running. Running speed, jump height, foot angle, and jump angle are some of the kinematics analysis variables observed (Otsuka & Isaka, 2019; A. Salo & Grimshaw, 1998; A. I. T. Salo & Scarborough, 2006). The height and angle of the jump are important variables that determine the athlete's success in passing the hurdle. The kinematic analysis has the potential to provide the ideal recommendation for each athlete to improve their performance.

Hurdles Clearance Technique of the Professionals

Technical mastery is key to the success of a sport (Hassan & Morgan, 2015). Professional athletes do not show significant differences in their technique. According to the study of Čoh et al. (2020), the height difference is often highlighted when looking at the techniques of professional athletes. This difference is due to the difference in velocity of each athlete. The height distance between the body and the hurdle indicates the effectiveness of the professional athlete's technique. Furthermore, the effective results were influenced by the structured training method.

The Application of Technology in Hurdling Training

Technology has developed rapidly in the 21st century (da Silva et al., 2023). These developments have made significant changes in sports (G. Li & Huang, 2020). The role of technology in sports is presented through the application of a various kind of technology development and innovations to support sports activities. Wearable devices are one example of technological developments in sports (Wang, 2017). Falbriard et al. (2020), also tried to develop wearable devices to measure the jumping height and the body angle. It aims to measure the effectiveness of the movements made by athletes. The results of these measurements were used as evaluation material for athletes and coaches to determine the appropriate training program. The development of wearable devices that utilize magnetic components and sensor system were also carried out in hurdling training (Falbriard et al., 2020). However, there are some other potential improvements to enhance the utilization of the technology (Schmidt et al., 2020).

Sports Biomechanics Prevents Sports Injury in Hurdling Training

The kinematics analysis performed in sports biomechanics has another role, which is to assess the potential for injury related to the movements demonstrated by athletes (Saleh et al., 2021). The motion analysis result will be examined by a team of sports injury experts to prevent potential injuries (Hao, 2017). Motion observation could be conduct-

ed by analysing the joint position or range of motion (ROM) of an athlete's body (Ahmad et al., 2017). An effective ROM decreases the injury risk of the athlete, and vice versa (Park et al., 2020). Li (2014), explained that the support of the feet during take-off and landing will be considered to minimize injuries to the knees and ankles during hurdling training and competition. In conclusion, sports biomechanics has the potential for injury screening and evaluation for every sport, especially hurdling athletes.

Conclusions

Sports biomechanics research in hurdling shows a dynamic development trend. The result of the systematic review shows that sports biomechanics research on hurdling training is more focused on analyzing two-dimensional kinematics. The analysis was focused on hurdling athlete's range of motion (ROM), speed, and height. In addition, the application of technological advances could potentially be developed further. Recent studies show more reviews related to injuries in hurdles sports. This statement is evidenced by the screening results using the PRISMA method and only obtained 15 relevant articles. Furthermore, sports biomechanics research in hurdling training could be inquired about broader and more varied factors correlating hurdles.

Based on these research data, the researcher suggests that in future research, more in-depth research can be carried out related to sports biomechanics in hurdling training. Analysis of kinetics such as leg muscle power, agility, or flexibility of athletes can be studied in future research. In addition, research using special technology, artificial intelligence, and big data for hurdling training and talent scouting can also be done. Thus, the development of research in hurdles can be more widespread and experience a significant increase.

Acknowledgment

The Authors would like to thank Universitas Negeri Surabaya, Indonesia, for providing the necessary financial support and resources to conduct this study. Special thanks to the National Dong Hwa University (Taiwan), Institut Teknologi Bandung (Indonesia), Universitas Kristen Satya Wacana (Indonesia), and Shanghai University of Sport (China) for the collaboration and support in conducting the research.

Conflict of interest

The authors has declared that there is no conflict of interest.

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Аналіз спортивної біомеханіки тренувань з бар'єрного бігу: Систематичний огляд

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 1 табл., 3 рис., 44 джерел.

Історія питання. Бар'єрний біг є динамічним і технічно складним видом легкої атлетики. Для забезпечення оптимальної технічної підготовки та досягнення високих результатів необхідна унікальна комбінація швидкості, спритності, координації та сили. Здатність досягти успіху в цьому виді спорту залежить від володіння спортсменом зазначеними компонентами, що призводить до зростання інтересу до цього виду спорту з боку дослідницької спільноти в спортивній науці.

Мета дослідження. Мета цього дослідження полягала в оцінці існуючих наукових праць у галузі спортивної біомеханіки щодо поліпшення показників результативності у бар'єрному бігу.

Матеріали та методи. Дослідження проведено із використанням методології «Переважні елементи звітування для систематичних оглядів та мета-аналізів» (PRISMA) задля аналізу релевантної літератури. Загалом 15 наукових статей, опублікованих між 1990 і 2023 роками, були визначені як такі, що відповідають тематиці дослідження, і відібрані для проведення поглибленого аналізу.

Результати. Отримані результати показали, що дослідження спортивної біомеханіки тренувань з бар'єрного бігу переважно зосереджені на таких ключових сферах: аналіз кінематики, застосування технологій та вивчення потенційних ризиків травматизму. Незважаючи на значний прогрес, досягнутий у розумінні біомеханіки тренування бар'єрного бігу, в даній науковій праці вказується на необхідність проведення подальших і більш комплексних досліджень. В рамках зазначених досліджень необхідно поглибити вивчення біомеханічних факторів, що впливають на результативність спортсменів з метою розробки оптимальних методів тренувань і стратегій щодо запобігання травматизму.

Висновки. Проведений аналіз підкреслює важливість продовження досліджень у цій галузі, оскільки потенційно сприяє вдосконаленню тренувальних підходів та покращенню показників спортивної результативності у бар'єрному бігу.

Ключові слова: тренування з бар'єрного бігу, кінематичний аналіз, застосування технологій, спортивні травми, кінетичний аналіз.

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Cite this article as: Ardha, M. A. A., Nurhasan, Supriyanto, C., Bikalawan, S. S., Yang, C. B., Putro, A. B., & Bimantoro, A. P. (2024). Analyzing Sports Biomechanics of Hurdling Training: A Systematic Review. *Physical Education Theory and Methodology, 24*(5), 842-850. https://doi.org/10.17309/tmfv.2024.5.20

Received: 12.08.2024. Accepted: 19.09.2024. Published: 30.10.2024

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ISSN 1993-7989 (print)
ISSN 1993-7997 (online)
ISSN-L 1993-7989

Теорія та методика фізичного виховання
Physical Education Theory and Methodology
Teorìâ ta Metodika Fìzičnogo Vihovannâ
Abbreviated key-title: Teor. metod. fiz. vihov.

Науково-методичний журнал
Scientific-methodological journal

Жовтень 2024. Том 24, № 5
October 2024. Vol. 24, Num. 5
https://doi.org/10.17309/tmfv.2024.5

Відповідальний за випуск О. М. Худолій
Комп'ютерна верстка М. О. Худолій
Коректор Є. Б. Бланк

Свідоцтво про державну реєстрацію серія КВ № 6255 від 21.06.2002 р. Засновник і видавець – ТОВ «ОВС».
Передплатний індекс **74667.** Адреса редакції: https://www.tmfv.com.ua.Тел.: (067) 578-40-08. E-mail: tmfv@tmfv.com.ua

Наказом МОН України від 26.11.2020 № 1471 журнал включено в категорію «А» фахових видань України.
Науки: фізичне виховання і спорт. Спеціальність: 017 – Фізична культура і спорт (26.11.2020).
Науки: педагогічні (26.11.2020). Спеціальності: 011 – Освітні, педагогічні науки (26.11.2020);
014 – Середня освіта (за предметними спеціальностями) (26.11.2020).

Підписано до друку 28.10.2023. Формат 60×84 1/8. Папір офсетний. Гарнітура Таймс. Друк офсетний.
Ум. друк. арк. 17,85. Обл.-вид. арк.18,5. Вид. № 05-2024. Зам. № 256. Тираж 300 прим. Ціна договірна.

ТОВ «ОВС» Україна, 61003 Харків, пл. Конституції, 18, к. 11.
Свідоцтво Держкомінформу України Серія ДК № 331 від 08.02.2001 р.
Зареєстрований в Національній раді України з питань телебачення і мовлення:
рішення No 1750 від 23.05.2024 р., протокол No 16, оприлюднено 23 травня 2024 р.,
ідентифікатор медіа – R30-04671
Друкарня ТзОВ «Цифра прінт». 61166, м. Харків, вул. Культури, 20-В